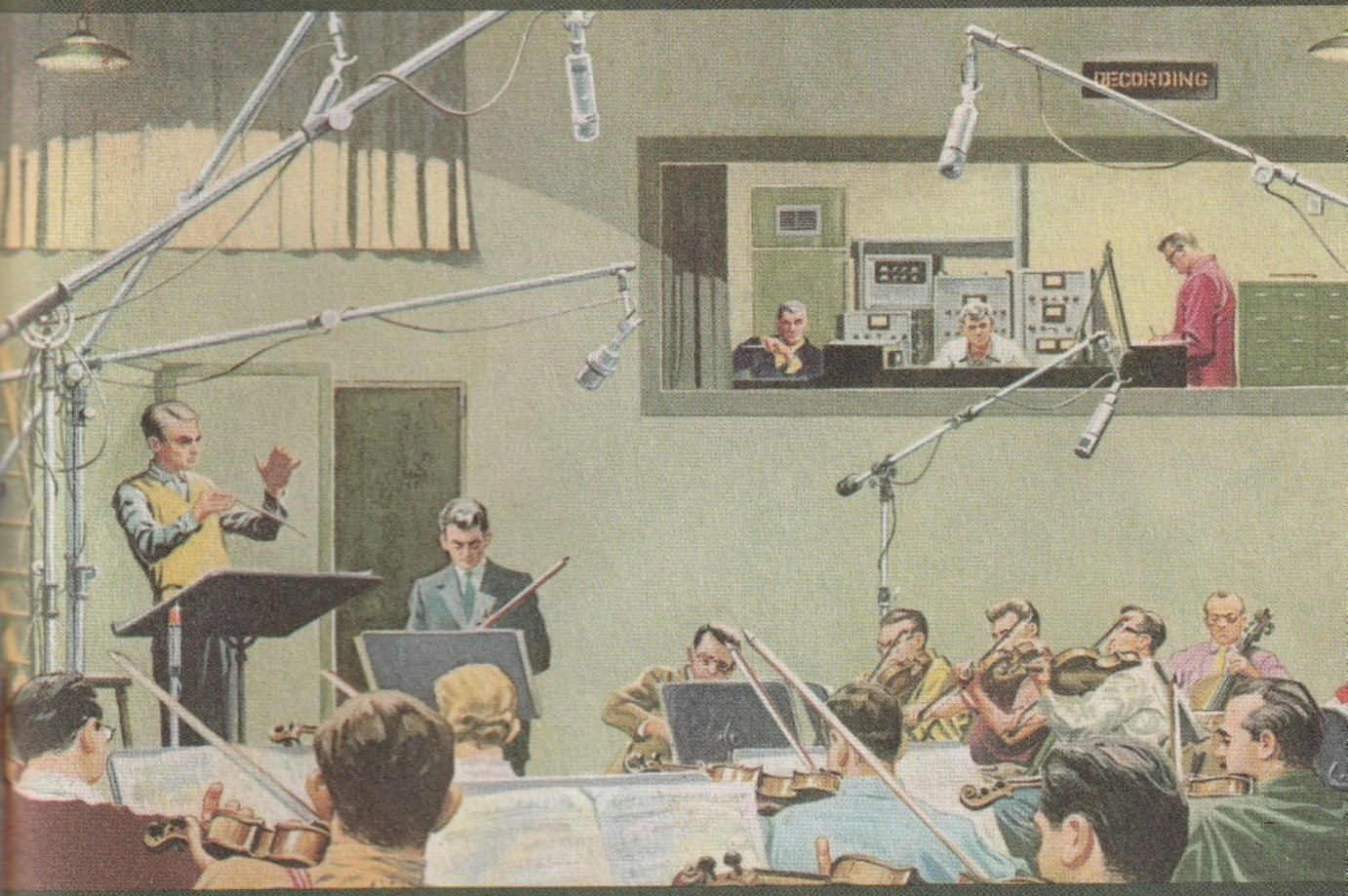
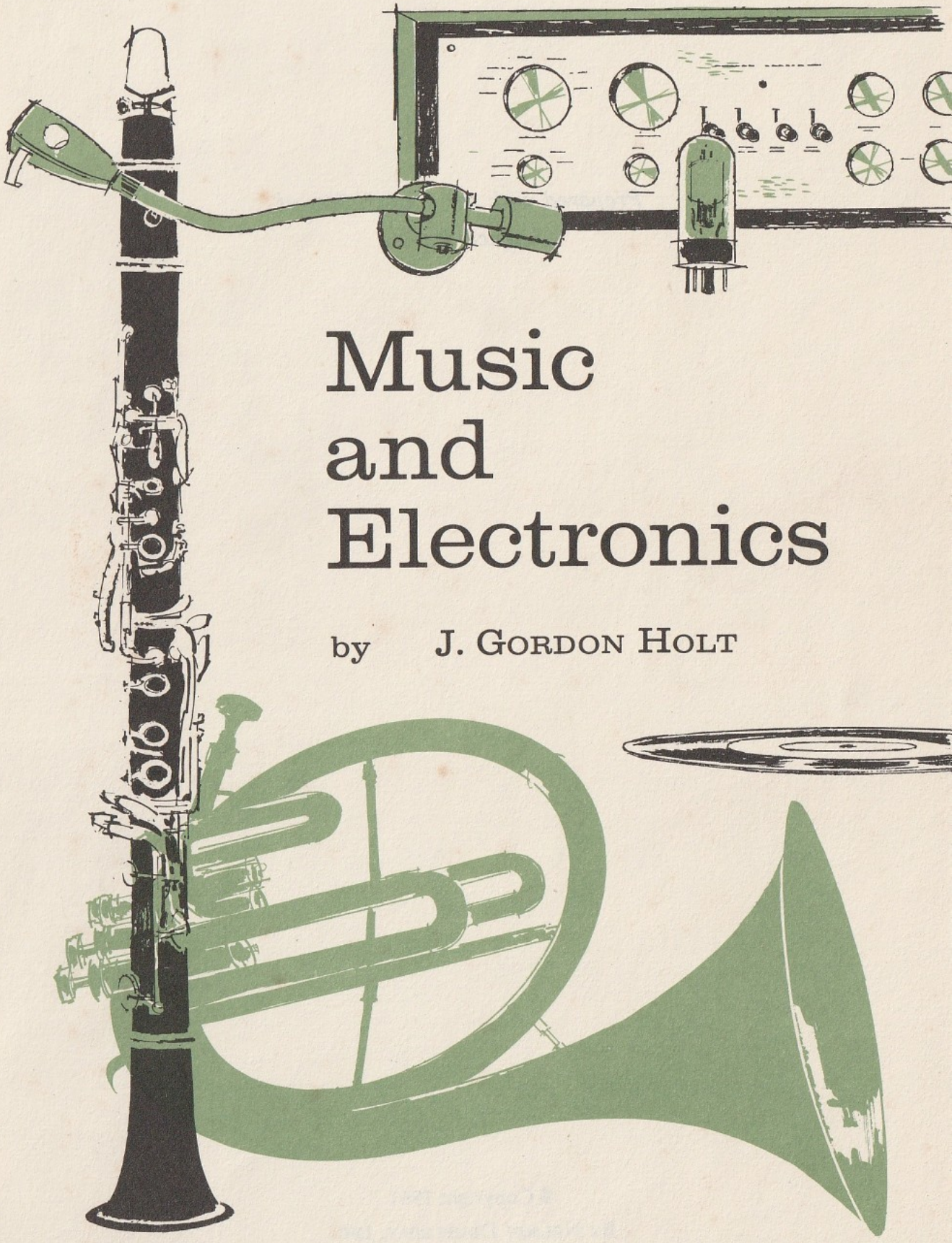
SCIENCE SERVICE SCIENCE PROGRAM

# Music and Electronics





# Music and Electronics

by J. Gordon Holt

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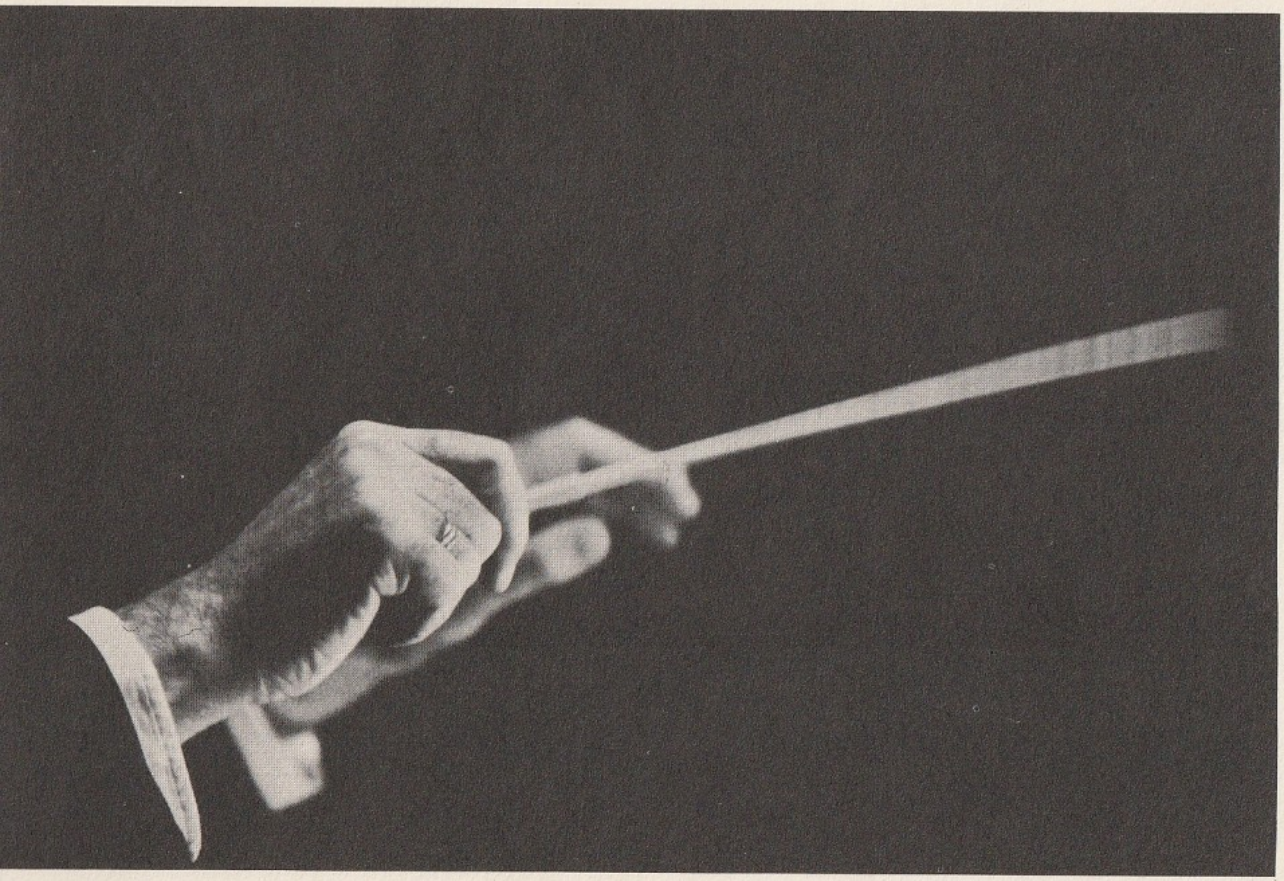
# MUSIC AND ELECTRONICS

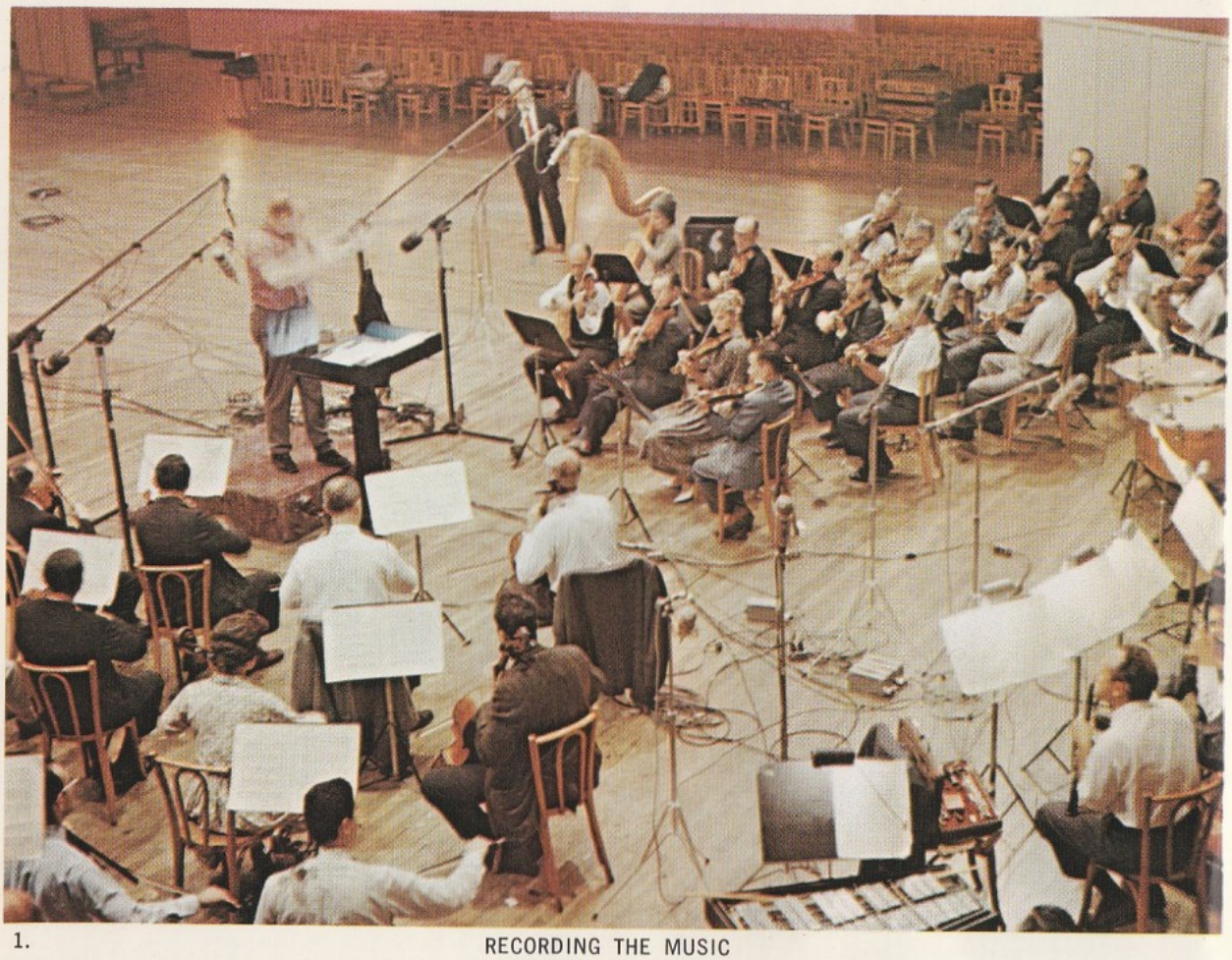


THE WARNING BELL SOUNDS, and the whispered conversation, squeakings of chairs, and shufflings of feet die down to a hush of tense expectancy. This is the final performance, the one that must be letter-perfect from beginning to end.

Eighty-four shirt-sleeved musicians raise their instruments, softly recheck their tuning for the fifteenth time, and watch the conductor's baton rise and hang poised in readiness. Finally, silence settles over the stage of Boston's famed Symphony Hall. Then a red light flicks silently on, the conductor lower his baton, and the entire orchestra plunges into the opening "Victory-V" bars of Beethoven's Fifth Symphony.

Flutists blow, violinists bow, and the percussionist wallops his kettle drums, and waves of rich sound spread out through the concert hall into the balconies and echo vastly through the rows of empty seats. For there is no audience to hear this performance. Instead of a thousand pairs of ears, the sounds are "heard" by a pair of microphones, small mechanical devices that resemble human ears in their task, but are made to convert sounds into tiny electrical impulses.

Ultimately, after these impulses have been strengthened, they are used to cut wavy grooves in a phonograph record that is later duplicated and sold in record stores. And finally, many months after the performance in Boston Symphony Hall, the impulses are reproduced in our living rooms as musical sounds, coming from a $29.95 portable phonograph or a $2,995 high-fidelity installation.

This is the story of living music in the home, and how electronics put it there.

1. RECORDING THE MUSIC

The first step in the making of a record: The music is played. Robert Irving conducts a performance of *The Seasons* by Alexander Glazounov for Capitol Records. This photograph was taken during one of the recording sessions at Manhattan Center in New York.

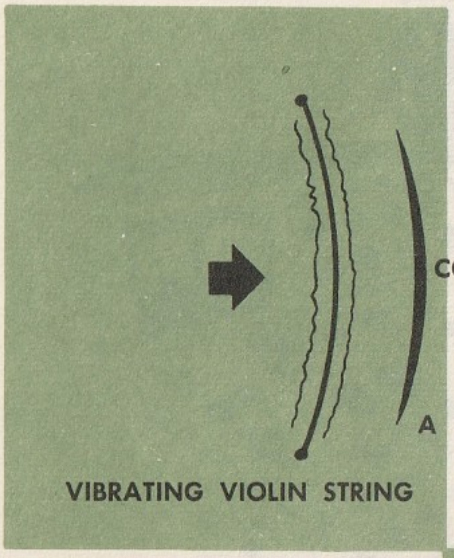
## *Music in the Air*

TO THE RECORDING ENGINEER, music is nothing more than a very complicated bunch of air vibrations.

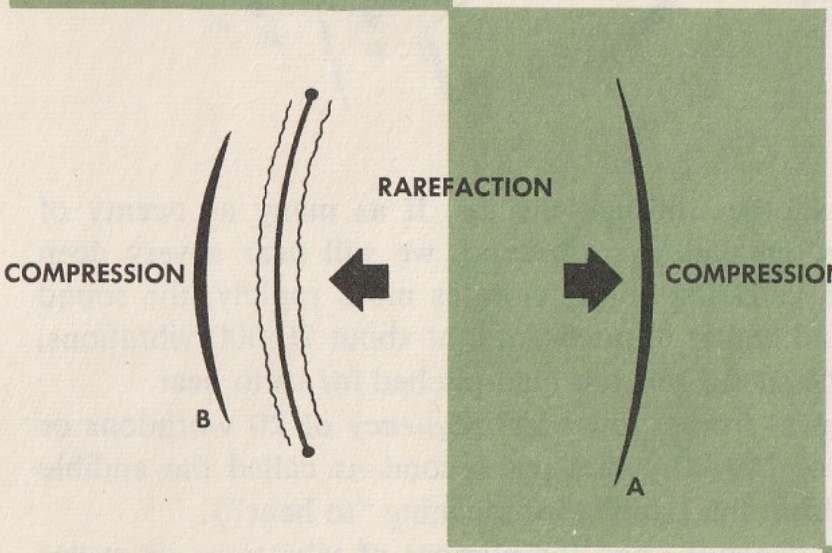
Anything that moves stirs up the air around it, sending out little waves of pressure. If we stand in the way of these pressure waves, they will move our eardrums in and out, but this doesn't necessarily mean we will hear something. The changes in air pressure must occur fairly *rapidly* before we can hear them as sounds.

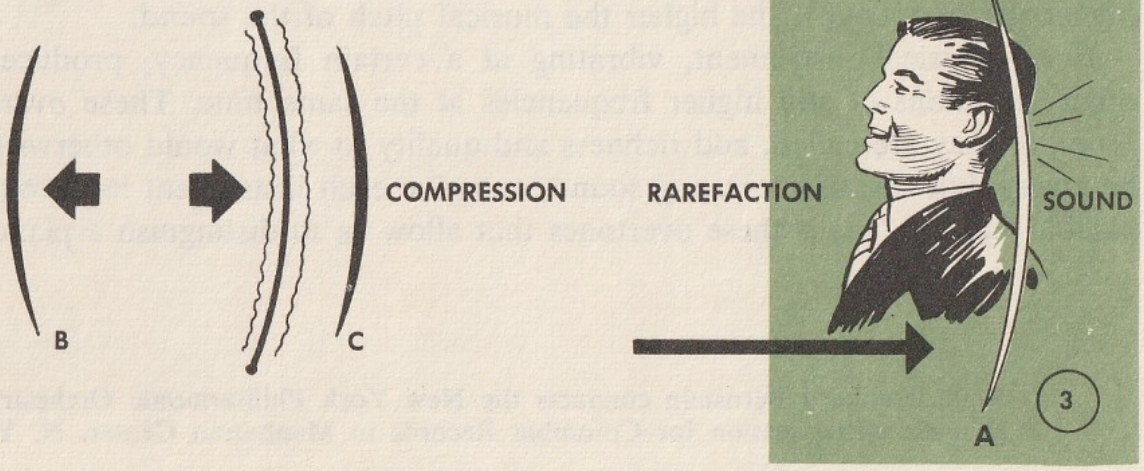
All sound waves travel through the air at the same speed, so the more times an object moves within a second of time, the closer the pressure

## AIR VIBRATIONS MAY BE HEARD AS SOUNDS




NORMAL AIR PRESSURE



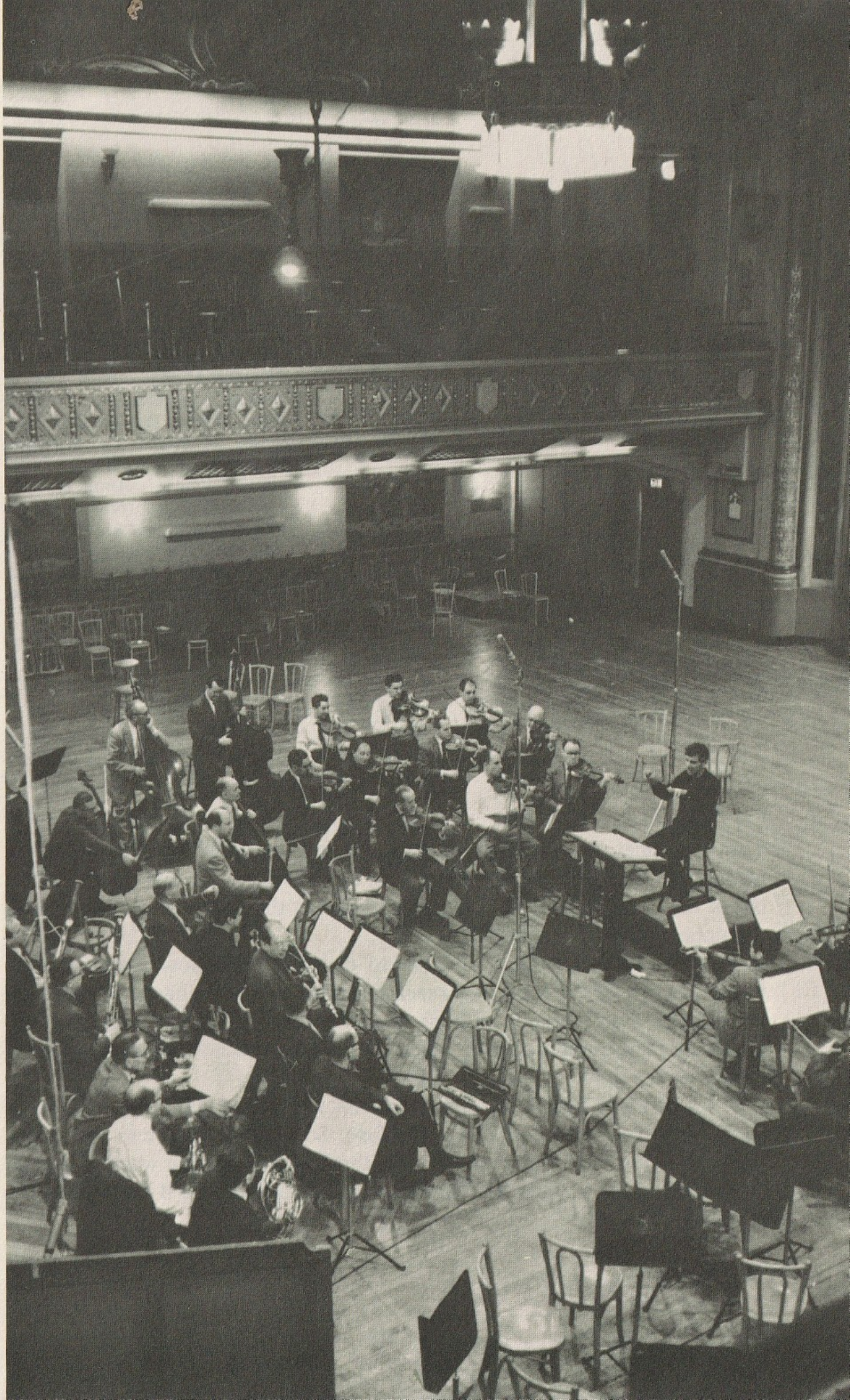


waves will follow one another through the air. If as many as twenty of these sound waves pass our ears every second, we will hear a very deep rumbling sound. As the vibrating object vibrates more rapidly, the sound is heard to get higher and higher in pitch until, at about 20,000 vibrations, or *cycles,* per second, the sound gets too high-pitched for us to hear.

This wide span of tones—from a low-bass *frequency* of 20 vibrations or cycles to a high treble of 20,000 cycles per second—is called the audible range (or *audio* range, from the Latin word meaning "to hear").

The *pitch* of a sound depends upon the number of vibrations or cycles that occur every second. Thus, the more vibrations per second (that is, the higher the frequency), the higher the musical pitch of the sound.

Every musical instrument, vibrating at a certain frequency, produces other vibrations of still higher frequencies at the same time. These *overtones,* as they are called, add richness and quality to what would otherwise be a very dull and uninteresting sound, and give each instrument its recognizable "quality." It is these overtones that allow us to distinguish a piano

*Right:* Leonard Bernstein conducts the New York Philharmonic Orchestra at a recording session for Columbia Records in Manhattan Center, N. Y.

2. PREPARING THE MASTER TAPE

After a musical work has been recorded and edited, it must be "mastered," the crucial step of transferring from tape to disc. Here, one of this country's top audio engineers, Dr. Rudolph van Gelder, adjusts the level control before cutting an acetate disc. This process requires extreme skill since, no matter how good the master tape, a finished record can never be better than the original acetate disc.

from a clarinet, even though both are playing the same note. Some instruments give off relatively few overtones, while others put out a large number of them, some of them so high in frequency that they are almost beyond the upper range of our hearing.

The *volume* or loudness of a sound depends upon how strong the air vibrations are by the time they reach our ears. A small change in air pressure causes a soft sound, or none at all. If the air pressure changes very much, as in a thunderclap or when an atom bomb is exploded, we hear a very loud sound.

A lot of atom bombs have been set off in New Mexico, yet no one in New York has ever heard the explosions. So from this we can see something else: the farther a sound travels through the air, the weaker it gets. Even the loudest sounds will become too soft to be heard if they travel far enough.

Standing in front of his Scully lathe cutter, Dr. van Gelder examines the grooves in an acetate disc he is cutting. He is looking for correct groove formation, correct depth, and sufficient groove separation. It is quite possible that Dr. van Gelder mastered some of the records in your own collection. See if you can find "RVG" engraved in the vinyl just outside the label.

3. CUTTING THE ACETATE

We can now hazard an educated guess at what must be done in order to reproduce a musical sound in our living room. All we need do is create in the room the same set of air vibrations that were originally made by the orchestra in Boston Symphony Hall, complete with all their volume variations, pitch combinations, and overtones. This is simple enough in theory, but in practice it's a pretty tall order.

## WHAT IS HIGH FIDELITY?

A PERFECT REPRODUCER OF SOUND re-creates everything that was present in the original sound, without subtracting anything from it or adding anything to it. Perfection is something that can never quite be attained, but it *is* a goal that can be aimed at. And while the best radios

This little girl is obviously thrilled with her record player. Yet it is probably the lowest fi possible, and she has to turn it by hand.

and phonographs come surprisingly close to perfection, most of them fall far short of it in many ways.

*Fidelity* means truth or faithfulness, so the best sound reproducers are termed *high-fidelity* reproducers. And, of course, the worst ones are called low-fidelity or "low-fi" reproducers. But what about the ones in between? Are they low-fi, or hi-fi? Where do we draw the line?

The fact of the matter is that we *can't* draw a definite line between low-fi and hi-fi, because the definition of high fidelity is useless as a *measure* of it.

High fidelity is not a kind of sound, or a kind of phonograph record; it is a degree of quality. Substitute the word "quality" for the word "fidelity," and the true meaning of high fidelity will become clear. A high-fidelity phonograph is nothing more than a high-quality phonograph, and high quality is a matter of one's own personal judgement.

If we know the things that go to make up a quality product (or an accurately reproduced sound), we can apply these standards to the thing

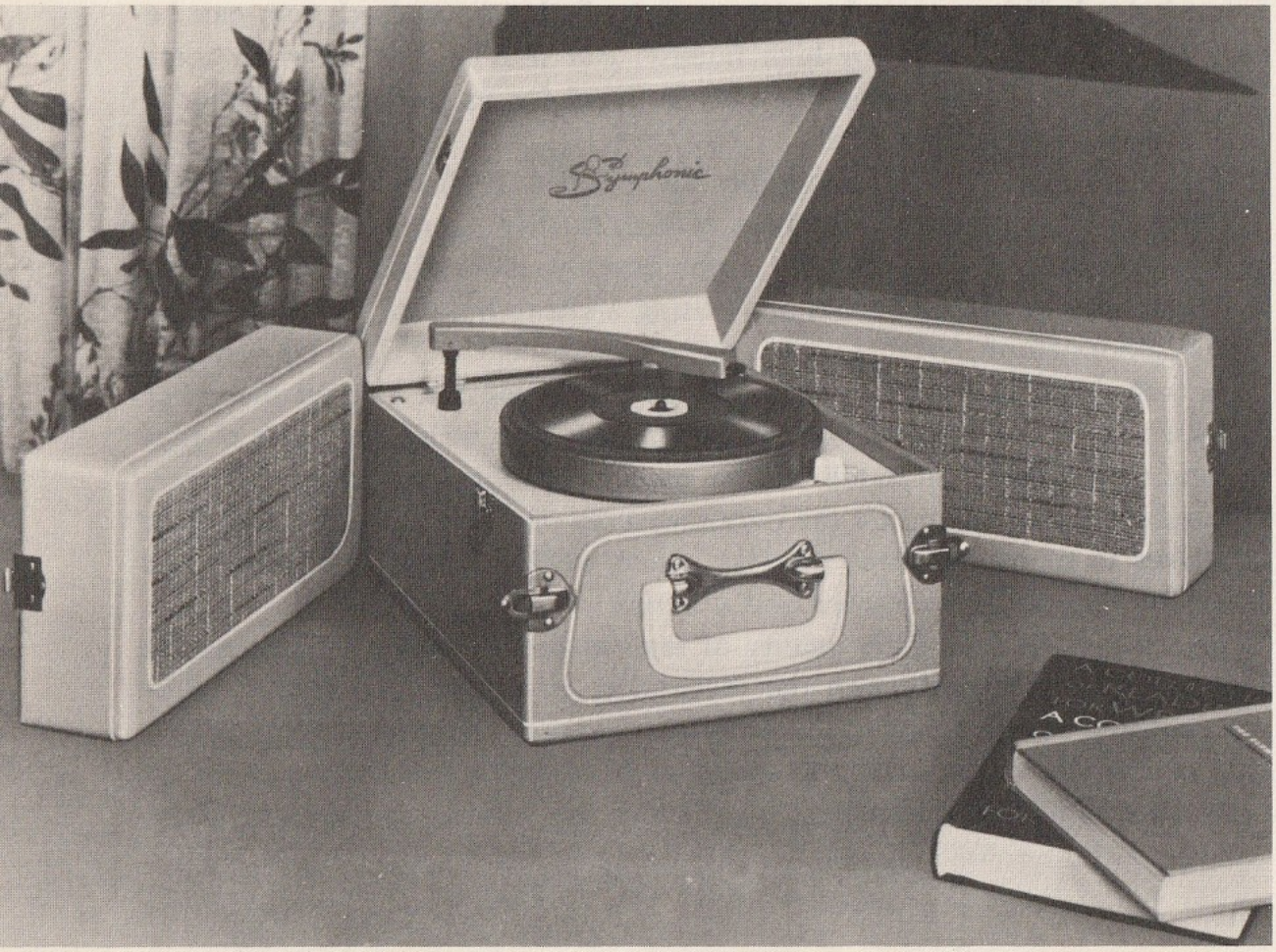
being judged. If it comes close to meeting all these standards, we can be certain it is high quality, or high fidelity. But if it is quite poor in some respects, yet is good in others, it may be hard for us to decide whether it is a high-quality product or not.

The mere fact that a phonograph has a tag on it that says "True High Fidelity" is absolutely no guarantee of high fidelity either, because there is no *legal* definition of high fidelity. Consequently, there is no law to prevent a dishonest manufacturer from advertising a cheap hunk of junk as a high-fidelity phonograph.

A truly high-fidelity phonograph is *always* expensive, but on the other hand, so are a lot of not-so-good phonographs. This means we can't always depend on the price tag to tell us how good a reproducing system is, either. Naturalness and realism are the only measures of fidelity, and we can train ourselves to recognize these qualities when we hear them, by learning to listen for two things: *presence* and *absence*.

Presence is an intangible quality of realism that gives us the impression that we are listening *through* the reproducer to the original sound, without anything between us and the performers except distance. A phonograph that is deficient in presence will sound as if there's a soft curtain hung up between us and the performers, deadening the sounds and making them

The dividing line between hi- and lo-fi is purely personal. This all-in-one stereo console may or may not delight you. It depends on where you draw your own personal "line."



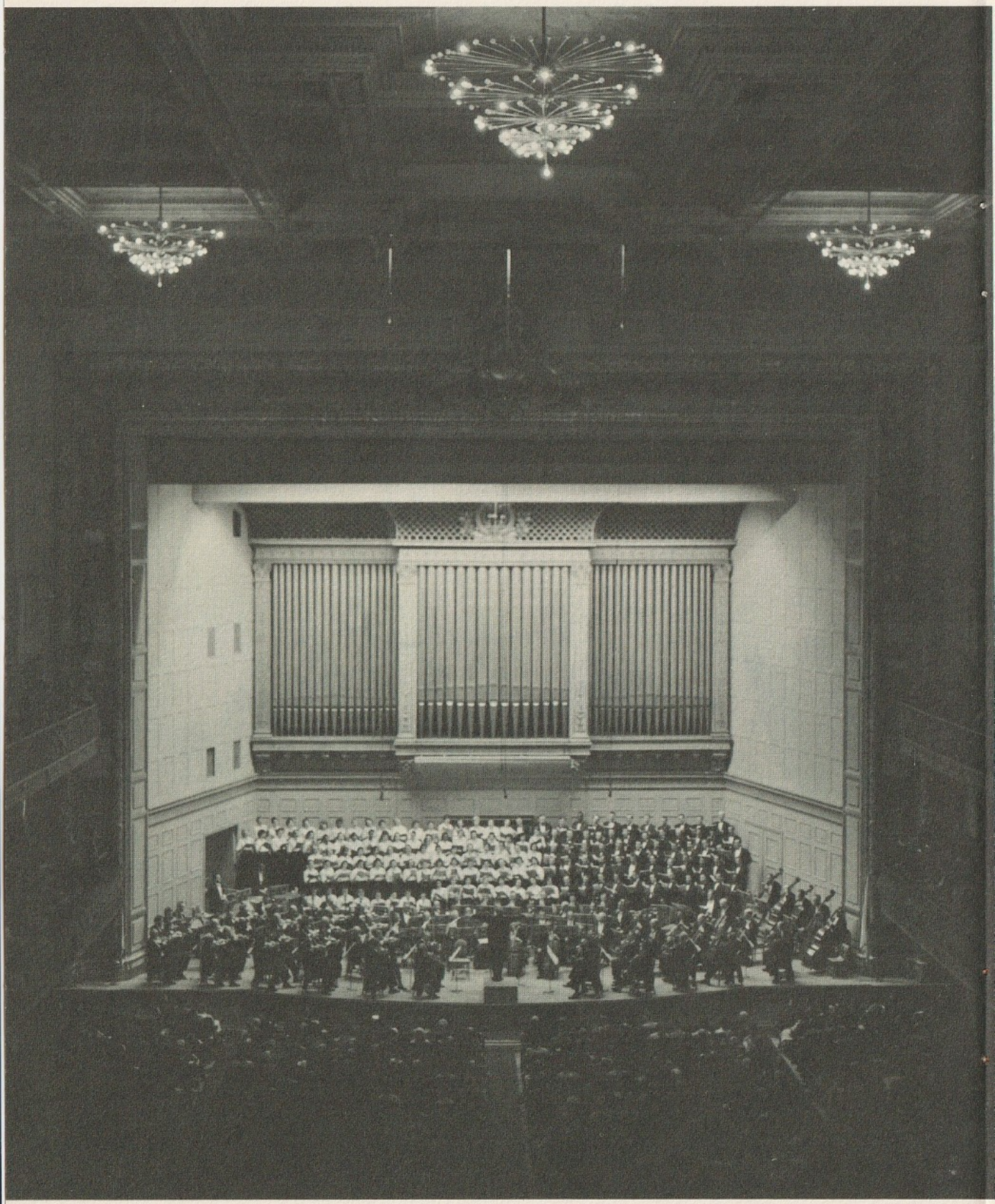

How hi is *your fi?* For a limited amount of money, this portable stereo phonograph will indeed provide hi-fi. It does not claim to be the highest fi attainable. On succeeding pages you will see hi-fi equipment in which quality comes first. Their manufacturers know that those people who insist on having the best are prepared to pay for it. The individual listener must decide whether he wants the equivalent of a Cadillac or a compact.

"mellow" or dull-sounding. To achieve full presence, the reproducer must not subtract anything from the original sounds, nor emphasize any of them out of proportion to the others. At the same time, it must not *add* anything new to them, either.

If the reproducer adds its own sounds to the original ones, the sounds we hear will be a combination of both, and will have lost some of their fidelity. Rumbles, booms, grating noises, and shrillness are among the things a low-fi phonograph can add to the sound. Other signs of less-than-perfect-fi are humming sounds, buzzes, hisses, rattles, loud clicks and pops, foggi-

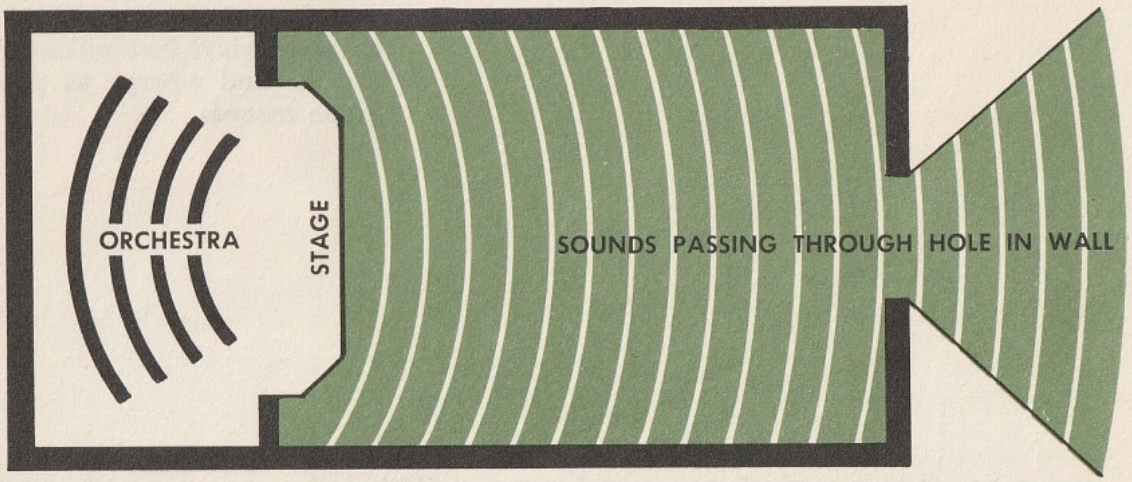
ness (as if the sound is fluffy and out of focus), and assorted "colorations" that make voices sound as if they are coming from inside a rain barrel or an upturned wastebasket.

All reproducers add some of these unpleasant qualities, to a greater or lesser degree, and the more they add, the lower their fidelity. In the almost-perfect reproducer, all unwanted sounds are virtually absent, which is what we mean when we say it has "absence."

The human ear is sometimes easy to fool, so rather than rely entirely on their ears, engineers supplement their hearing with instrument tests and measurements. A complete set of these technical *specifications* can often give almost as good an idea of a reproducer's quality as can a listening test. People who have learned to interpret specifications can tell from them which of the various reproducers listed in catalogues best suit their needs, without ever seeing the equipment itself. The non-technical person, however, would do best to rely on his ears, or consult someone who understands this engineering data.

## *Holes in the Wall*

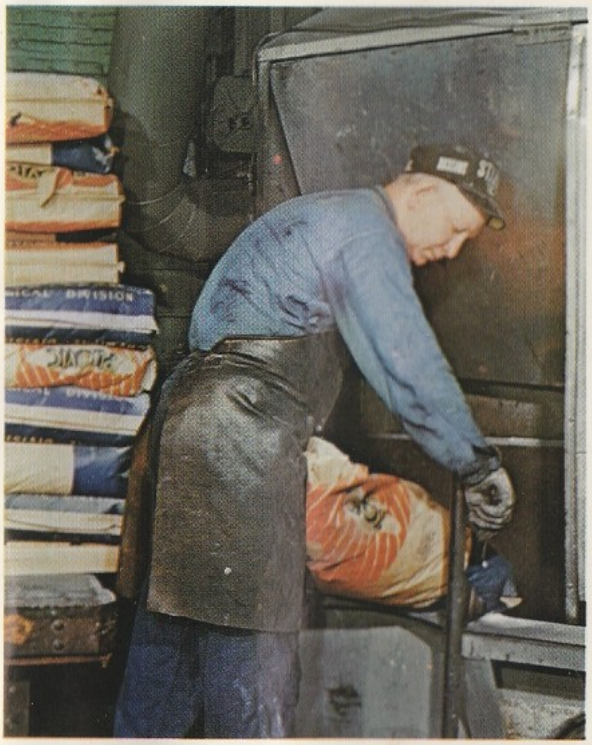
THE SOUNDS IN A CONCERT HALL — that is, the air vibrations set up by the orchestra — travel away from each instrument and out into the hall until they hit the walls and ceiling, where many of them are absorbed by the draperies, plaster surfaces, carved decorations, and so on. The remainder are reflected as echoes.

If we were to cut a hole in the middle of the concert hall's back wall, sound waves that would normally hit that part of the wall would escape,




and could be heard quite clearly by someone standing outside the hole. He would hear all the original volume variations, overtones, and the full tonal range of the orchestra, along with some of the echoes caused by unabsorbed sounds bouncing back and forth between opposite walls. But there's one thing he would *not* hear: the *directions* from which all these sounds are coming. To him, they would all seem to be coming from the same place — from the hole in the wall. He would not get any impression of the size of the perfoming group or the spaciousness of the hall itself. To do this, there must be *two* holes in the wall.

Because our ears are located on opposite sides of our head, each ear tends to favor the sounds closest to it. A sound originating from the left is picked up more strongly by the left ear, and our brain tells us that the source of the sound is to the left. A sound coming from directly in front is picked up equally by both ears, and when this happens the brain tells



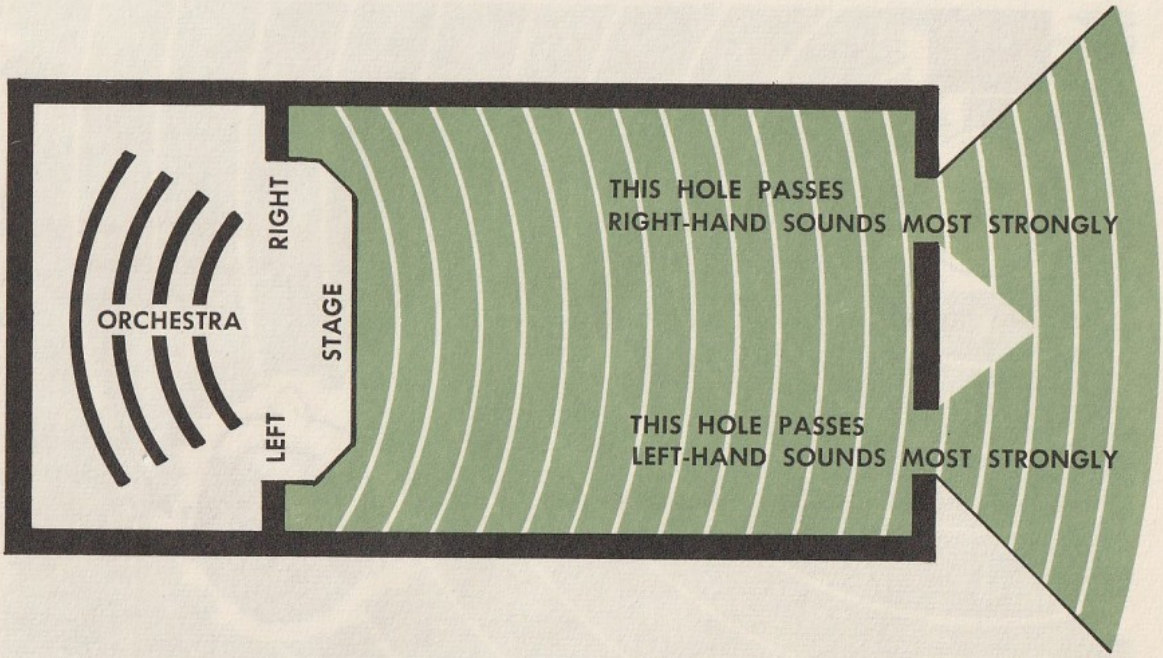
4. RAW VINYL POWDER

At the record company's pressing plant, the raw materials are poured into a hopper before being mixed, heated, and formed into thin, black rectangular "biscuits" of vinyl that will later be pressed and emerge as phonograph records.

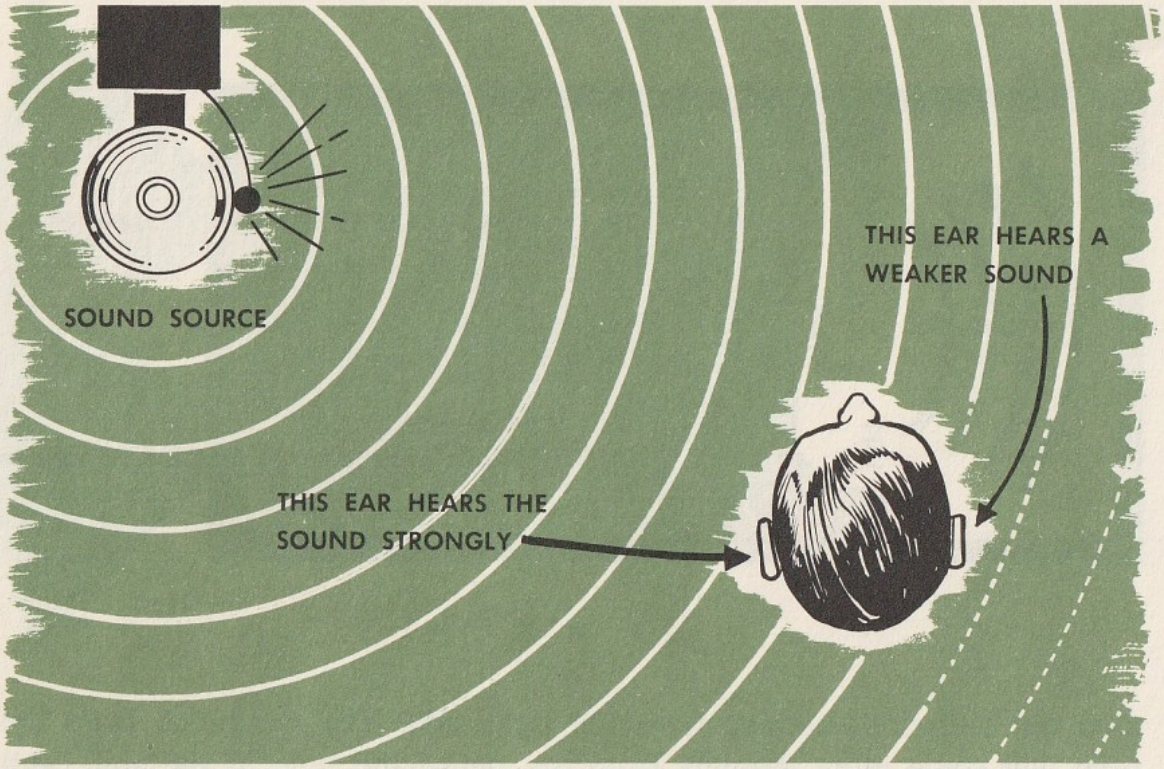
us the sound is coming from straight ahead. This is how we are able to tell where a sound is coming from, even though we can't see what is making the sound. It is also what enables us to "focus" on a sound, as it were, so we can pick it out from a lot of other sounds. Try holding a conversation in a noisy restaurant with your finger in one ear, and you'll see how important two-eared, or *binaural,* hearing is to us.

When we listen to the single hole in the wall, we can locate the direction of the hole, but everything coming through it is mixed together so that both our ears hear the same thing. We may be listening with both ears, but it doesn't do us any good; as long as both ears hear exactly the same thing, the sound will lack direction and dimension. We cannot tell from where behind the hole the sound came originally. This is called *monophonic* (single-channel) sound and is the kind of sound we get from a conventional radio or phonograph, hi-fi or otherwise.

But let's see what we would get from *two* holes in the back wall, spaced some distance apart. The hole at the left will be closer to the instruments on the left-hand side of the stage, and will pass their air vibrations more strongly



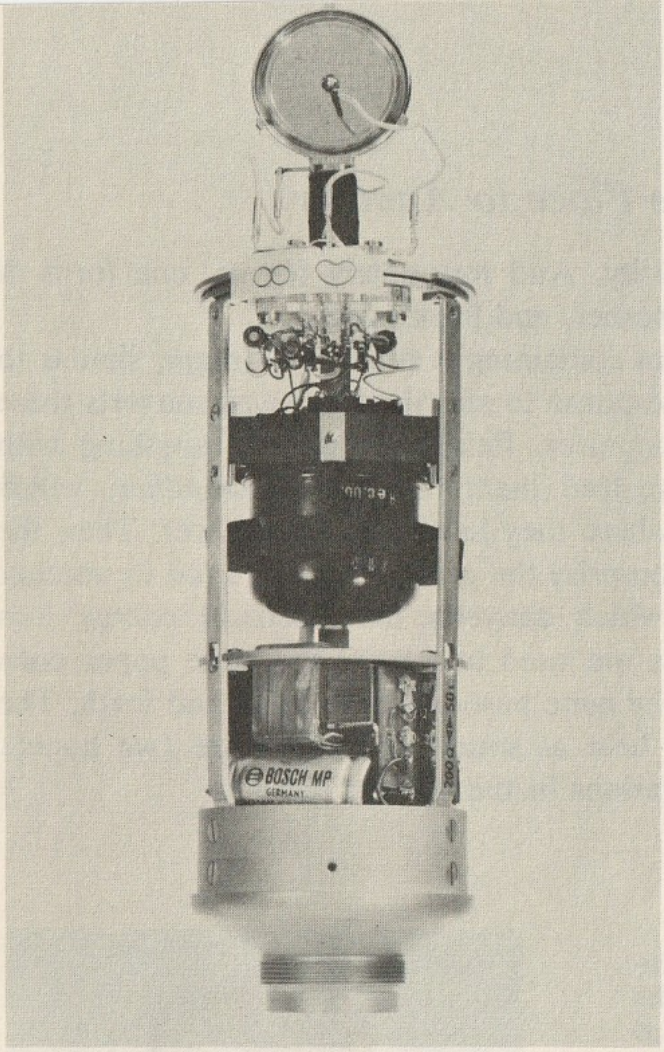

than the vibrations coming from the right side. The vibrations from the right will come more strongly from the right-hand hole in the wall, and those coming from the center of the stage will be passed equally by *both* holes. If we stand outside the auditorium now, our ears will tell us that different parts of the orchestra are located in different places, and we will seem to hear the entire panorama of sounds from the instruments spread




across the stage. We will even "hear" sounds coming from *between the holes,* because when both ears hear equal volume, the brain locates the sounds directly in front of us. We will hear "direction" in some of the echoes in the hall, too, and will get a remarkable sensation of the actual size of the hall. This is *stereophonic* sound—sound with depth and perspective.

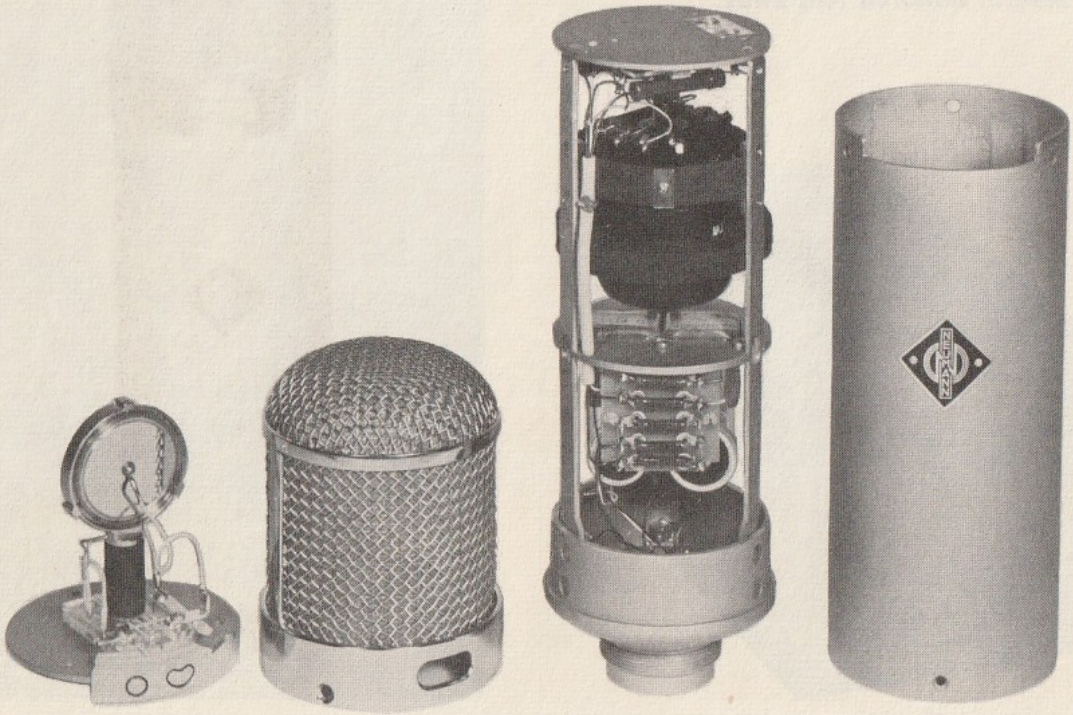
Now, suppose we tack a very thin, light piece of cellophane over each of these holes. They will be closed up, but the variations in air pressure in the auditorium will hit the cellophane sheets and vibrate them in and out. Their outer surfaces will then set the outside air in vibration, just as if the cellophane sheets were not there at all.

Let's take this a step further, and move the cellophane sheets into holes in the wall of our living room, attaching to the back of each sheet an ingenious device that vibrates it exactly the way the original air vibrations did. We would hear exactly the same sounds as we heard from outside the concert hall. And that is how a stereophonic reproducer works, although the home reproducer does not use cellophane sheets. It uses a pair of loudspeakers, usually large paper cones, and vibrates them by means of electric currents.




For a microphone to be able to *transduce* sounds from pressure waves into electrical energy with complete accuracy requires the type of precision workmanship found in this German-made Neumann U-47 condenser model.

*Left:* The U-47 with its casing removed. *Below:* The U-47 disassembled one stage further. The microphone sensing element is at the top and also at the bottom left.

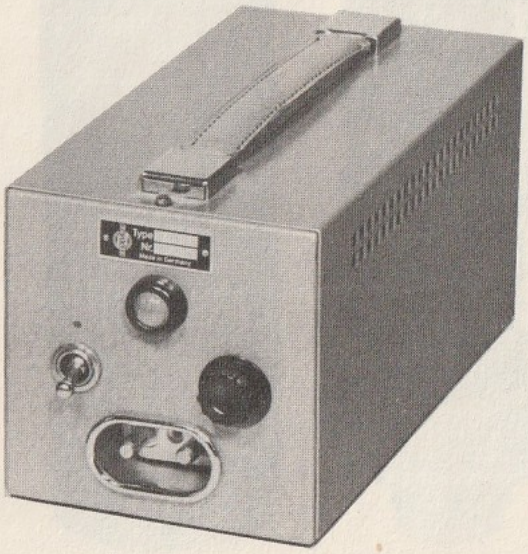


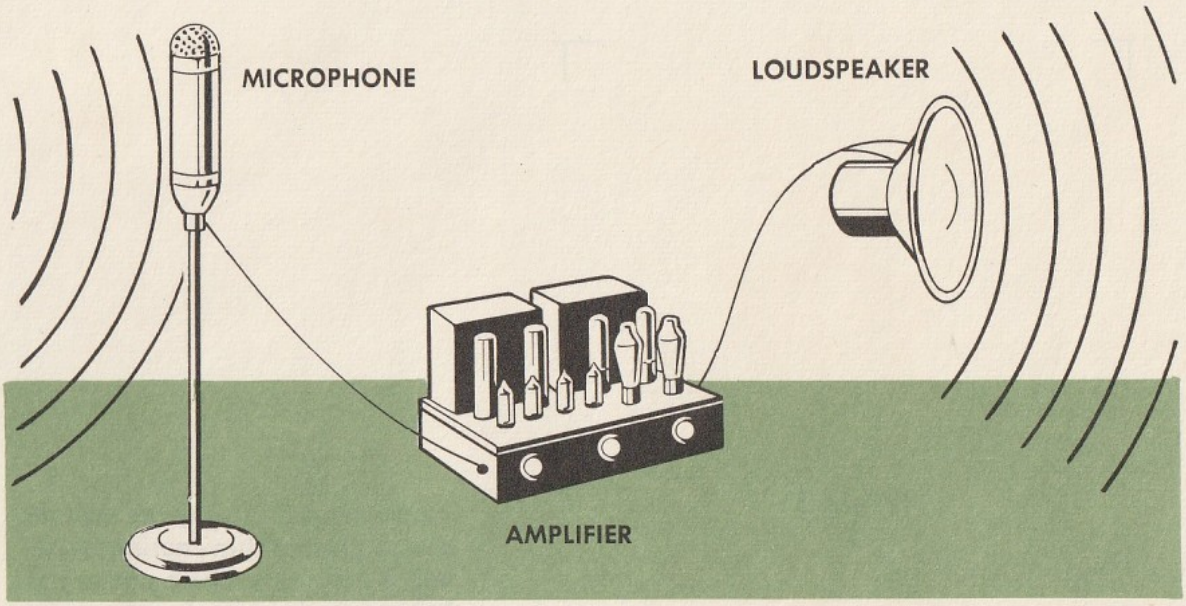
## *From One Place to Another*

SOUND IS ENERGY; so is electricity. And fortunately for us, one form of energy can be converted into another, and back again.

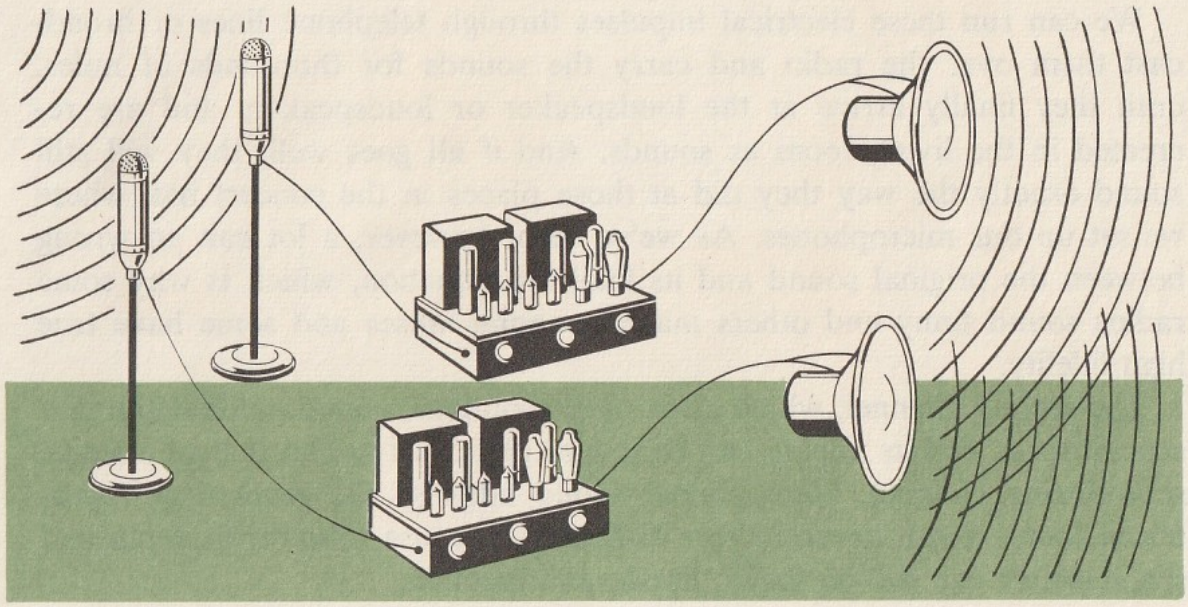
A *microphone* is a mechanism containing a small diaphragm, similar to our eardrums, that vibrates in response to air vibrations and converts these vibrations into tiny electrical impulses. Before we can do anything with these feeble impulses, we must feed them through an *amplifier,* which strengthens them to the point where they have far more power. Then the strengthened impulses, which comprise the *audio signal,* are fed to another device called a *loudspeaker,* which converts the electrical energy into motional energy. These motions are used to vibrate the large paper cone we mentioned previously, and the cone pushes the air back and forth. The result: air vibrations which we hear as sound and which are (we hope!) identical to the original air vibrations in the concert hall.

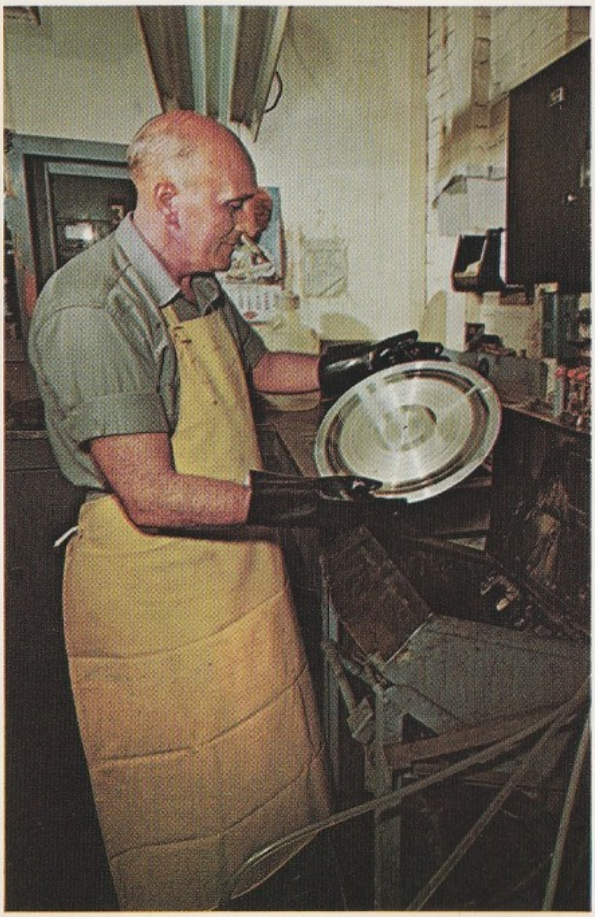
This Neumann U-47 condenser microphone is one of the standards in the recording industry. The microphone is plugged into its power supply unit, *below,* and this in turn is plugged into the tape recorder which may be as much as several hundred feet away.






If we run a long wire from the amplifier to the loudspeaker, we can put the loudspeaker several blocks down the road and carry the musical sounds much farther than they would travel if we simply opened up the wall of the concert hall and set the sounds free in the air. If we are dissatisfied with the lack of spaciousness we get from this single-channel *(monophonic)* arrangement, we can put *two* microphones side by side, feed each to a separate amplifier, and run *two* long wires to a pair of loudspeakers placed side by side. This, of course, will give us stereophonic sound.





5. SILVERING THE ACETATE

At the record factory the acetate disc is given a thin coating of silver. Later, this silver coating is backed up by nickel and copper and will be peeled away to become the "master." Only one side of an acetate is cut, therefore there are two masters for each record. More masters are needed if a large number of records is to be manufactured.

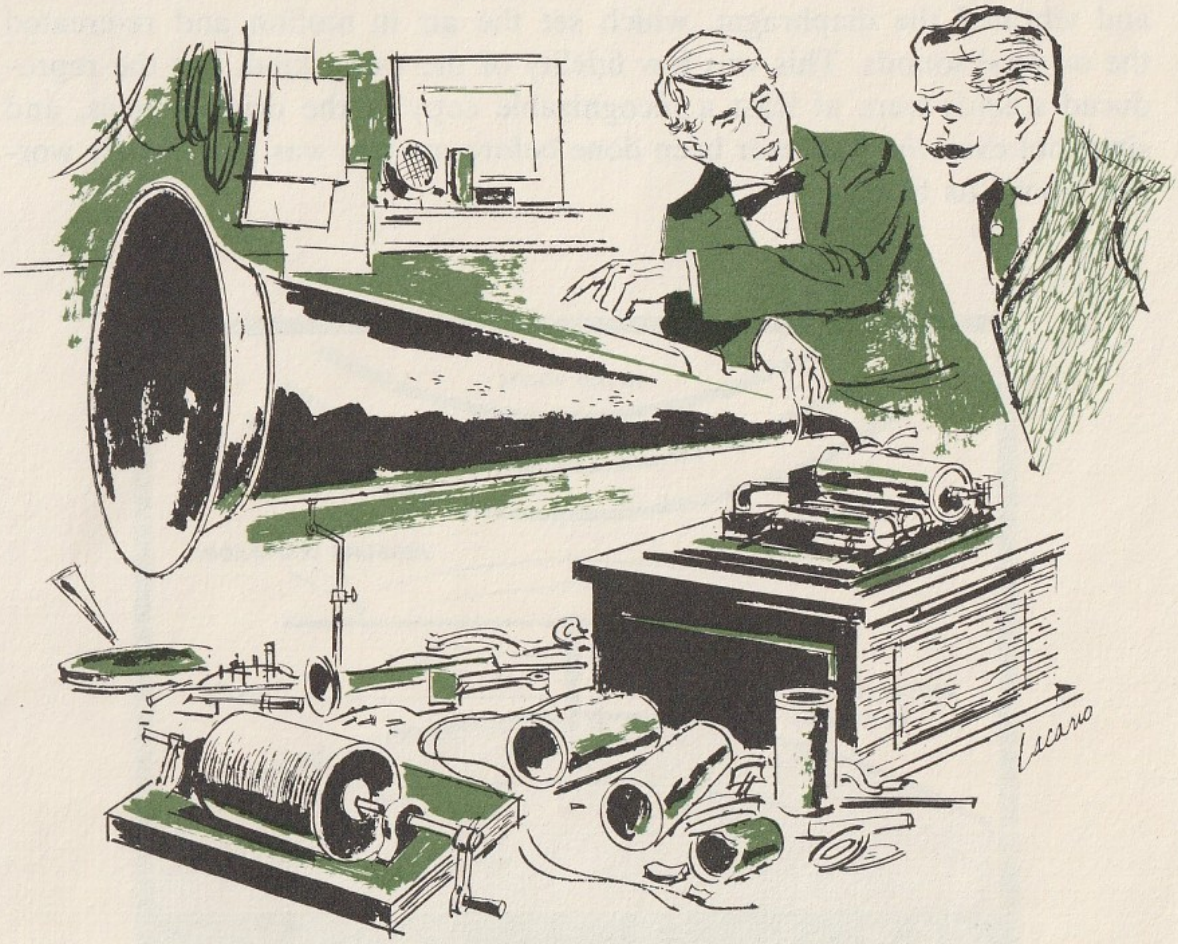
We can run these electrical impulses through telephone lines or broadcast them over the radio and carry the sounds for thousands of miles, until they finally arrive at the loudspeaker or loudspeakers and are recreated in the living room as sounds. And if all goes well, they will still sound exactly the way they did at those places in the concert hall where we set up our microphones. As we've seen, however, a lot can go wrong between the original sound and its final reproduction, which is why some radios sound tinny and others make booming noises and some have true high fidelity.

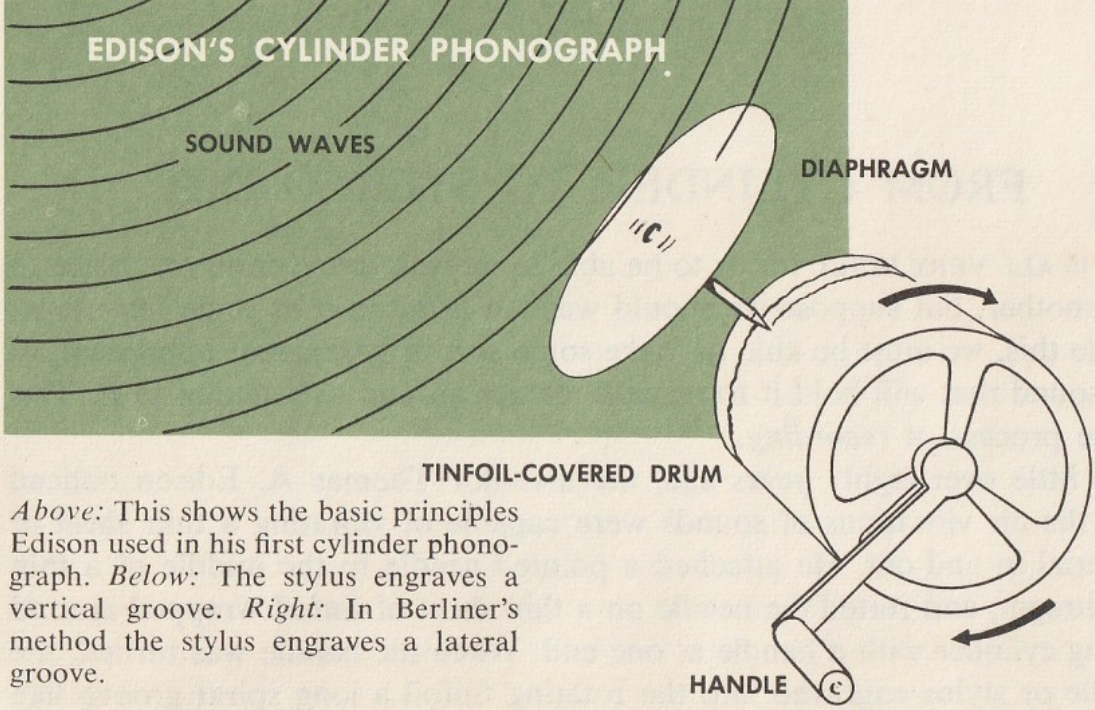
The second channel, which gives us stereophonic sound, adds depth and spaciousness, but its fidelity can be low or high, just as can that of a single reproducing channel. Stereophonic sound adds to the realism of reproduced sound, but it doesn't affect its fidelity, because sound with depth and spaciousness can still be foggy, harsh, and metallic.

# FROM CYLINDER TO STEREO DISC

IT IS ALL VERY WELL for us to be able to move a sound from one place to another, but suppose we should want to listen to it at some *later* time. To do this, we must be able to make some sort of permanent impression of the sound that will hold it fixed until we get around to listening to it. This is the process of *recording*.

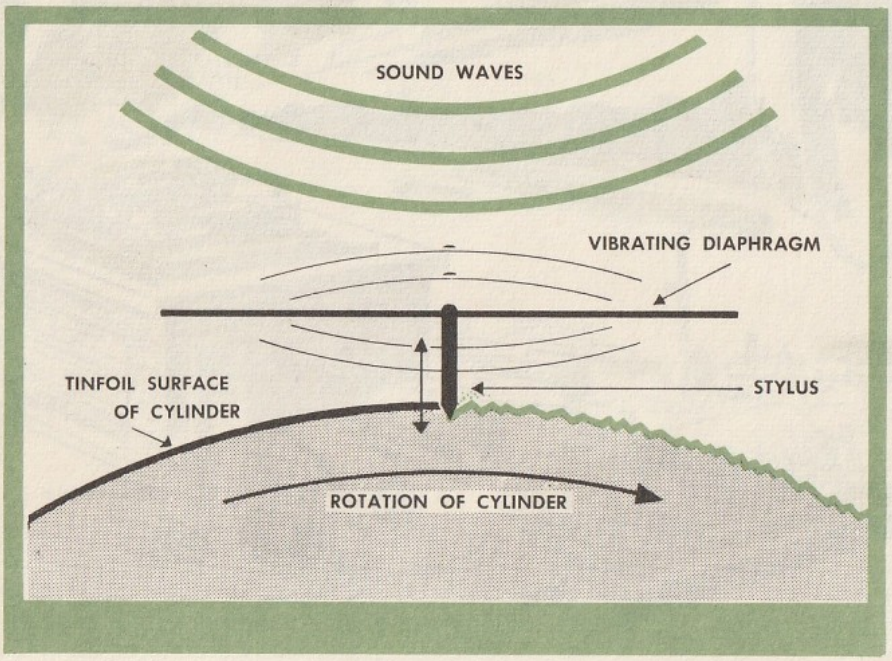
A little over eighty years ago, the inventor Thomas A. Edison noticed that the air vibrations of sounds were capable of vibrating a thin sheet of material in and out. He attached a pointed needle to the middle of a thin diaphragm, and rested the needle on a thin sheet of tinfoil wrapped around a long cylinder with a handle at one end. When the handle was turned, the needle or stylus engraved into the rotating tinfoil a long spiral groove like the threads of a screw. When sound waves were directed at the diaphragm, it would vibrate the stylus up and down, varying the *depth* of the groove it was making in the tinfoil.

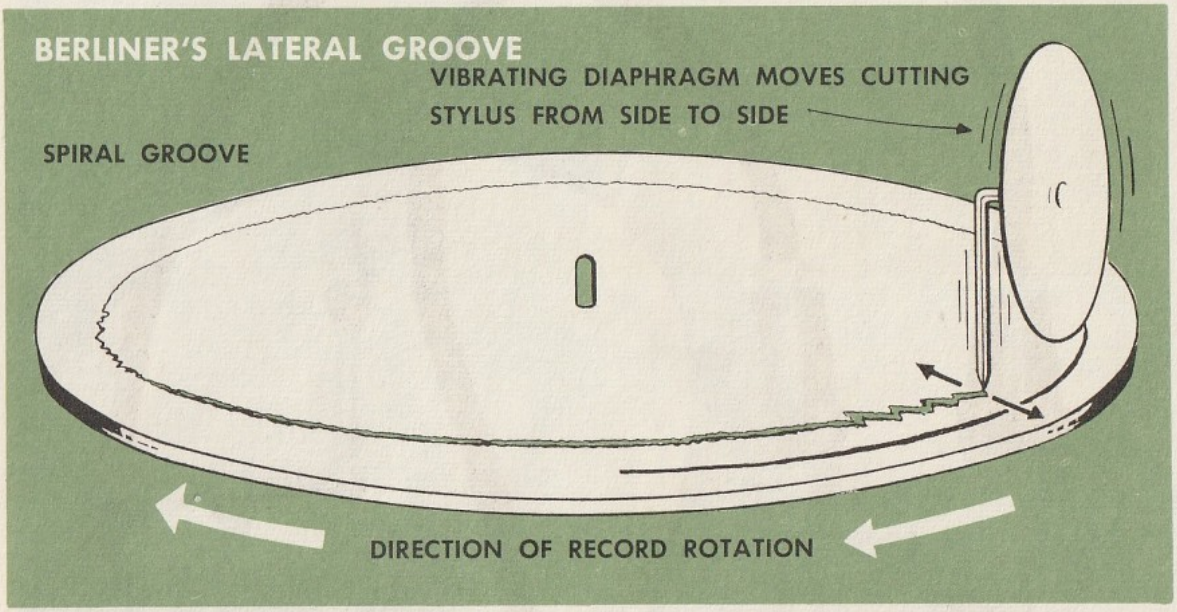





*Above:* This shows the basic principles Edison used in his first cylinder phonograph. *Below:* The stylus engraves a vertical groove. *Right:* In Berliner's method the stylus engraves a lateral groove.

When the tinfoil drum was turned past the stylus a second time, the stylus wiggled up and down (over the wiggles in the bottom of the groove) and vibrated the diaphragm, which set the air in motion and re-created the original sounds. This was low fidelity of the worst kind, but the reproduced sounds were at least a recognizable copy of the original ones, and since not even *this* had ever been done before, no one was particularly worried about its fidelity.



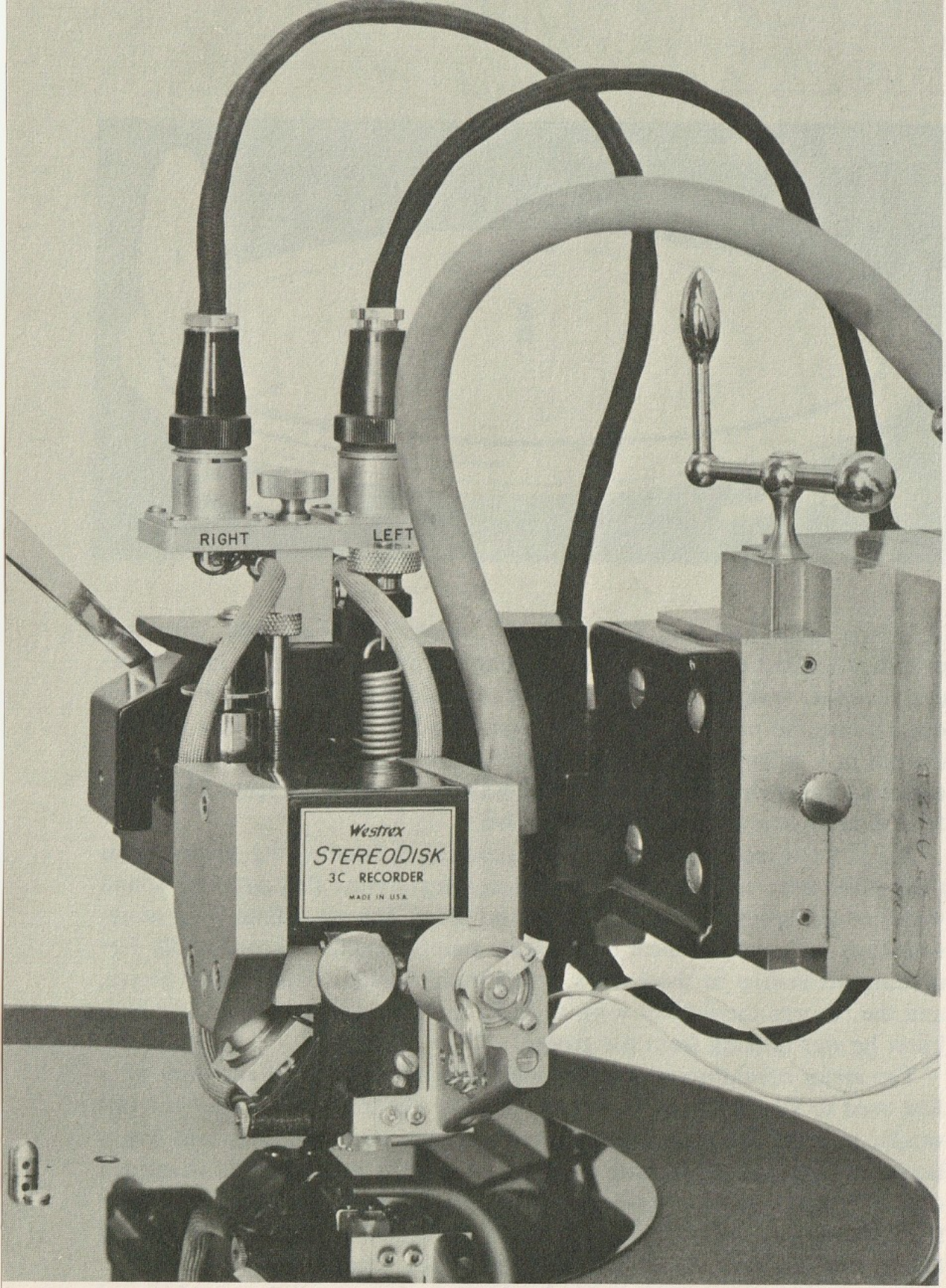

BERLINER'S LATERAL GROOVE
VIBRATING DIAPHRAGM MOVES CUTTING STYLUS FROM SIDE TO SIDE
SPIRAL GROOVE
DIRECTION OF RECORD ROTATION

Edison made and sold a lot of his "cylinder" phonographs, with wax cylinders instead of the noisy, crinkly tinfoil ones. Ten years later, however, another inventor, Emile Berliner, took Edison's basic idea and developed it into the phonograph as we know it today. Berliner used a flat disc instead of a cylinder, and cut his spiral groove from the outer edge to the center of the record. He also devised a way of vibrating the recording stylus from side to side instead of up and down.

All of these recordings were made acoustically; that is, the sound waves themselves were used to vibrate the recording stylus. But airborne sound waves could do just so much work and no more. The recordings were tinny-sounding, and some musical instruments simply wouldn't record at all. Recording orchestras in those days didn't even include a bass fiddle player, and the records themselves were so sadly lacking in bass that no one ever knew he was missing from the group.

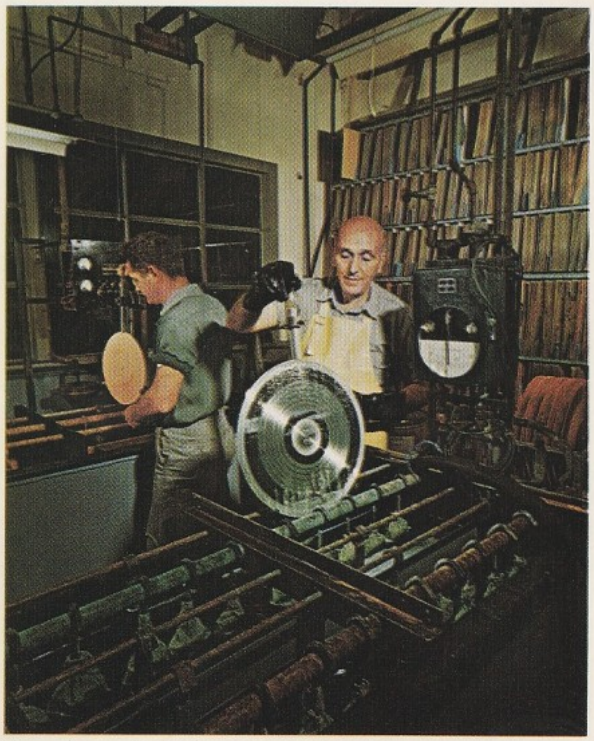
The major breakthrough came when a microphone and an amplifier were first used to vibrate the recording stylus. The electrical *recording head* was similar to a loudspeaker in that it converted electrical impulses into vibrations. But instead of pushing a paper cone back and forth, it wiggled a sharp cutting stylus from side to side while the stylus cut its groove into the rotating wax disc. Then the disc was duplicated by the thousands, in a harder material that would better withstand the wear of frequent playings.

The playing stylus (or *playback* stylus) had a tiny little rounded and polished tip and was mounted in a *pickup*. This in turn was attached to the end of a *tone arm* that was hinged at the other end so it could follow the




Cutting a stereophonic acetate disc: This is a Westrex cutting head in position over an acetate blank whose mirror surface reflects the underside of the cutter. Notice the separate cables for each stereo channel.

When the acetate disc has been silvered, it is then dipped first in a nickel tank and then in a copper tank in order to build up the thickness of the master.



6. NICKEL AND COPPER PLATING

spiral groove toward the inside of the record. The pickup converted the side-to-side wiggles of the groove into electrical impulses, and these, like the original ones from the microphone, were amplified and used to drive a loudspeaker.

Today's long-playing records revolve at less than half the speed of the earlier ones, and this plus their much finer and closer-spaced grooves, gives them almost six times the total recording time of the earlier discs. Their fidelity is much higher, too; they have far less needle scratch, they give a wider range of volume variation (called *dynamic range)*, and they span the entire audible range of frequencies. But they are still nothing more than a drastic improvement of Berliner's phonograph record.

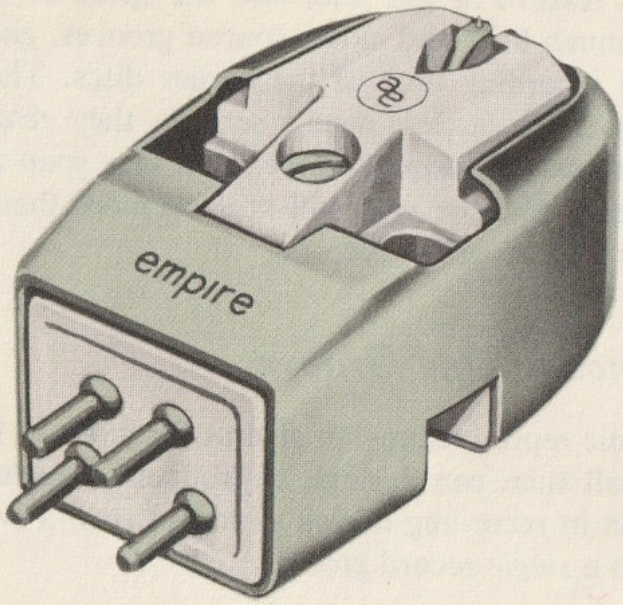
## *Two Sounds in One Groove*

WE HAVE SEEN HOW stereophonic reproduction can give us far more of the original sounds in a concert hall than can a single reproducing channel. Now the most recent innovation in recording allows us to put such a two-channel stereophonic signal into a *single* record groove.

The first stereophonic records had two concentric bands of grooves, and were played with two separate pickups and styli mounted on a fork-shaped tone arm. Each pickup and stylus fed a separate amplifier and loudspeaker, and when the speakers were placed side by side, the resulting sound had all the spaciousness and realism of two holes in the auditorium wall. This cut the playing-time of the record in half, however, and since both styli had to be in precisely the correct grooves to keep the channels in step with one another, the system was clumsy to use and hard to keep in adjustment.

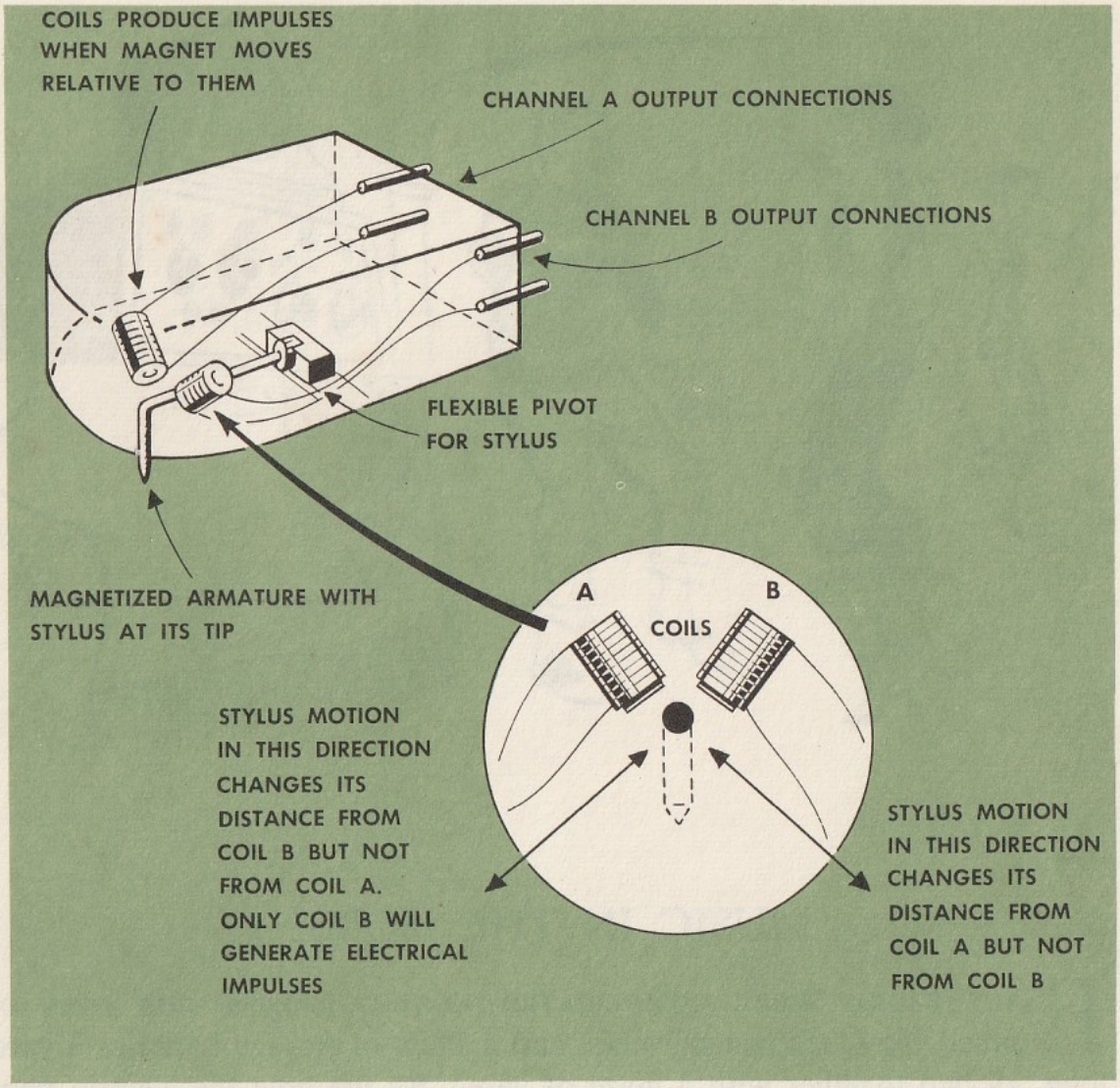
The modern stereophonic disc overcame both of these problems at once by enabling us to record the two separate signals in one groove.

Remember that sounds can be recorded as variations in the depth of a groove, or as side-to-side wiggles of the groove. It is no trouble to design a pickup that will respond to varying groove depth while remaining unresponsive to side-to-side, or lateral, motion. It is equally easy to make a pickup responsive to lateral motion but not to vertical motion. The trick is in orienting the pickup's energy-converting elements so that they respond when the stylus moves in one direction but not in the other. So it is not very much harder to make a pickup with *two* sets of elements in it, one set oriented to respond to vertical stylus motion and the other oriented to respond to lateral motion. When this pickup plays a vertical disc, the electrical impulses will come from one set of elements, while a lateral disc will send signals from the other set of elements. A cutting head of similiar design allows us to record one channel of the stereophonic program verti-




The stylus and its cartridge act as a transducer to reconvert groove variations into electrical signals. The Audio Empire 108 stereo cartridge is shown here. It is a good example of today's finest stereo cartridges.

## HOW A STEREO CARTRIDGE WORKS


COILS PRODUCE IMPULSES WHEN MAGNET MOVES RELATIVE TO THEM
CHANNEL A OUTPUT CONNECTIONS
CHANNEL B OUTPUT CONNECTIONS
FLEXIBLE PIVOT FOR STYLUS
MAGNETIZED ARMATURE WITH STYLUS AT ITS TIP
A
B
COILS
STYLUS MOTION IN THIS DIRECTION CHANGES ITS DISTANCE FROM COIL B BUT NOT FROM COIL A. ONLY COIL B WILL GENERATE ELECTRICAL IMPULSES
STYLUS MOTION IN THIS DIRECTION CHANGES ITS DISTANCE FROM COIL A BUT NOT FROM COIL B

cally and the other channel laterally; when the disc is played on our special pickup, we will get from it the two separate signals we need for full stereophonic reproduction.

This method of stereo recording was tried a few years ago, but it was found that better fidelity could be obtained by recording each signal as a *sloping* vibration up and down one wall of the V-shaped groove. The sensing elements in the pickup were similarly angled to the sides, so that each would respond to sloping motion in one direction but not in the other direction. The result: two signals of equal fidelity in a single groove, to give us the modern long-playing stereophonic record.

# MUSIC IN THE HOME

EARLY RADIOS WERE COMPLICATED-LOOKING gadgets with rows of tubes, big black transformers, and a stack of storage batteries a yard long, all tied together with a maze of wires. By the time the electric phonograph was being added to them, the whole "home entertainment center" had been encased in a neat wooden cabinet, where it stayed until about ten years ago.

During the late 1940s, some people were finding that they could obtain much better sound by purchasing professional reproducing *components,* such as those used by broadcasting stations, and putting these together themselves to make up a high-fidelity reproducing *system.* This idea caught on, and before long, component high fidelity had become a multimillion-dollar industry.

"Packaged" systems, in cabinets, have improved a lot since 1949, but the best sound is still obtained from component high-fidelity systems. This is because no single manufacturer makes the *best* of all the different com-

Science Bulletin
Prepared by SCIENCE SERVICE

INSTRUMENTS

Man has fashioned musical instruments in almost every culture and time known to historians and anthropologists, experts at the American Museum of Natural History in New York have determined. In this art of controlling the motion of air to produce sound, men in various cultures have used bamboo, wood, bronze, brass, gourds, silk, gut, vine, horn, tortoise shell, skin, and even human bone.

Whatever the construction, the sound is always produced in one of four ways.

In the simplest form of instrument, known as membranophones, sound is produced by striking or rubbing a stretched skin. Membranophones range from the simple frame drum to the sophisticated Indian tabla, a combination of two drums that vary in pitch.

In the second class, sound results when an enclosed column of air is set in motion. Aerophones, as instruments of this design are called, include horns, trumpets, mouth organs, flutes, whistles, and reeds. Almost all are played by blowing into the instrument. One notable exception, however, is the pan pipe from the Far East, which occasionally is played by firing it into the air, attached to a rocket.

Sound produced by plucking, bowing, or striking a string makes an instrument a chordophone. This group includes not only the harps, lutes, viols, zithers, and lyres, but also what may be the most primitive of all instruments, the musical bow.

The most varied group of all, the idiophones, require that the instrument itself vibrate and be self-sounding. Rattles, xylophones, and gongs belong in this last category. Like the membranophones, these instruments usually are used for rhythm rather than melody.

RARE BIRD

A chicken and a turkey have been crossed to produce the "churk," the first true hybridization of two families of birds. The mother is a white Beltsville turkey and the father is a dark Cornish chicken.

The history-making cross, achieved by Dr. Marlow W. Olsen of the poultry research branch of the U. S. Department of Agriculture, resulted by accident from experiments dealing with the parthenogenetic or fatherless turkeys developed three years ago by Dr. Olsen. Three churks are now living. They have the long neck and white skin of the turkey mother and the general size and dark-colored feathers of the chicken father. The neck is feathered but without wattles, and the legs are like those of a young turkey.

These birds, all of which are male, are dumb, silent, and weak. Their intelligence is about half that of the parent stock, and their chickenlike chirp is voiced only when they are disturbed. All the churks have defects, such as crooked legs or beaks; even their feathers grow in a twist.

Unless further crosses are made, these weird-looking creatures are doomed to extinction, for they are sterile and cannot reproduce themselves even if there were a female in the group.

DOOMSDAY

Doomsday is set for Friday, November 13, 2026. On this date, calculations indicate, human population will approach infinity, if it grows as it has grown in the last 2,000 years. At that point the human race will promptly annihilate itself. Dr. Heinz von Foerster of the University of Illinois and colleagues Patricia M. Mora and Lawrence W. Amiot believe their prediction of doomsday is accurate within ten years.

While the optimists consider growing population no problem because they believe food technology advances will provide for the masses, and the pessimists argue that there is a limit, the Illinois researchers state that both are wrong.

The principle of "adequate technology" has held for 100 generations, they say, and can be expected to last at least three more. But "our great-great-grandchildren will not starve to death. They will be squeezed to death."

CANCER PUZZLE

Chickens resistant to an infectious, leukemia-like cancer of the bone marrow and blood have been developed by U. S. Department of Agriculture geneticist Nelson F. Waters. The achievement indicates that animals can be bred for resistance to at least one form of cancer.

In studies conducted at East Lansing, Michigan, individual male and female White Leghorns were found capable of transmitting complete resistance against this particular type of cancer, known as erythroblastosis, to their offspring even though the other parent was genetically susceptible. This fact suggests that one pair of autosomal (not sex-linked) dominant, heredity-carrying genes may control the resistance.

Strangely enough, however, when resistant birds from two different lines of White Leghorns were crossed, the resistance disappeared. In some cases, 75 per cent of the offspring from such crosses died when inoculated with the erythroblastosis virus. At present there is no explanation for this peculiar phenomenon.

## MOON SAMPLER

Whether or not the moon is made of green cheese, granite, or a meteorite type of rock will be known with scientific accuracy in 1962, Dr. A. R. Hibbs of the National Aeronautics and Space Administration's Jet Propulsion Laboratory has stated.

The device slated to land on the moon's surface is an instrumented space vehicle known as Ranger A, advanced model III, IV, or V. After launch from an Atlas Agena rocket, the Ranger will take television scanning pictures every 12 seconds as it approaches the moon and will take a gamma-ray spectrum whereby the presence of potassium, a constituent of most rocks, can be determined. The vehicle also will find out whether the moon has radioactive materials, such as have been found in meteorites, and will measure the temperature of solar gas as it meets earth's upper atmosphere.

Upon landing, Ranger's seismometer will go to work, telling the mother planet whether or not the natural satellite is being rocked by crashing meteors.

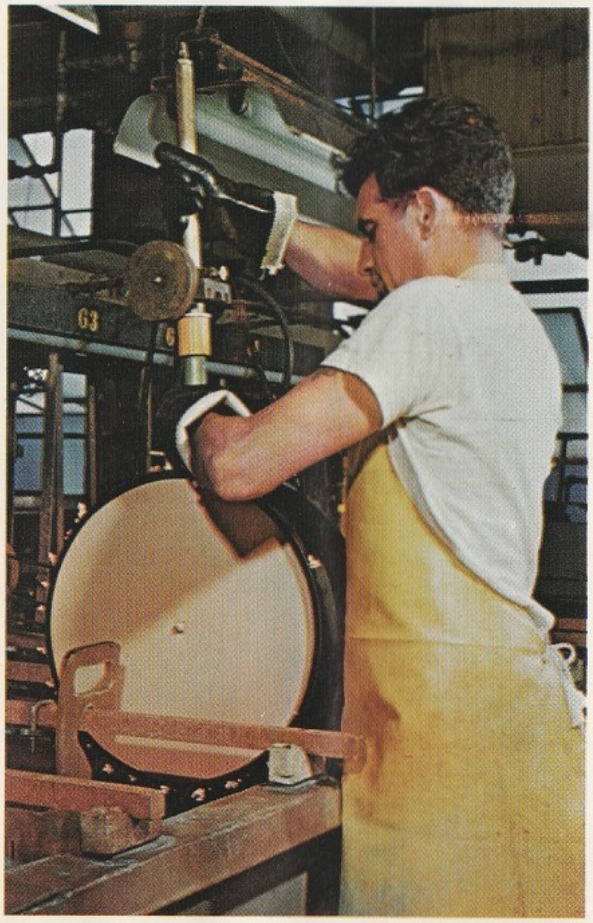
## IN SHORT

Gum diseases is responsible for the loss of more adult teeth than all other causes, including tooth decay.

Transport planes capable of carrying 150 passengers two or three times the speed of sound are being designed in Russia.

The faintest star known is 30 light years away and is 2,000,000 times dimmer than the sun.

Wearing rubber gloves and rubber apron, a Capitol Records technician lifts a "mother" from its copper plating tank. When the master was separated from the original acetate disc, it was then used to make the mother, which can be played for test purposes. The master cannot be played, since it has ridges instead of grooves.



7. PLATING THE MASTER

ponents that go to make up the reproducing system. To get the best system, it's necessary to purchase components made by different manufacturers.

The basic record-reproducing system consists of four components: the turntable, pickup, amplifier, and loudspeaker.

The *turntable's* sole function is to rotate the record at as constant and accurate a speed as possible, and with a minimum of vibration. All records are recorded at constant and accurate speed, and if they are played at a different speed, musical pitches and tempos will speed up or slow down. If the turntable's speed varies up and down, even by a very small amount, it will cause a wavering of pitches that is exceedingly annoying to a musically sensitive listener. If the turntable makes mechanical vibrations while it rotates, the pickup stylus will react to these vibrations as wiggles in the groove and will reproduce them along with the music as a deep rumbling sound.

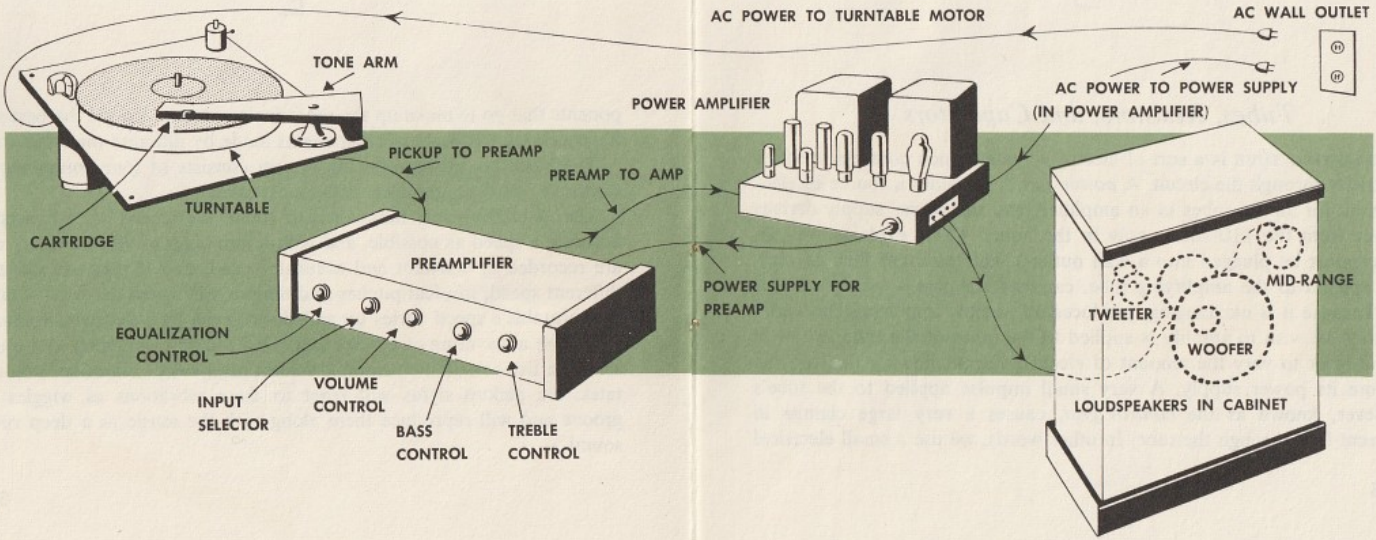
**PRECISION TURNTABLE, ARM, AND CARTRIDGE**
**by Audio Empire**

The *pickup* consists of two parts; the *tone arm* and the pickup *cartridge* with its stylus and vibration-sensing elements. The stylus is generally an integral part of the pickup, and sometimes is not even removable. The tone arm holds the cartridge in proper alignment with respect to the grooves, and allows the cartridge to swing freely across the record as the stylus follows the long, spiral groove. The arm's bearings should not impede the motion of the arm, and the whole pickup arrangement should be as free as possible from mechanical rattles or resonances which might vibrate the cartridge and be picked up as unwanted sounds.

Strictly speaking, the *amplifier's* only purpose is to make the electrical signals from the pickup strong enough to drive a loudspeaker. But there are several steps involved in this, each taking place in a different part, or *stage,* of the amplifier.

An amplifier stage consists of one or two *amplifying tubes,* with their associated *resistors* and *capacitors,* and the stage is generally named for what it does to the audio signal passing through it.

**MINIMUM BASIC COMPONENTS REQUIRED FOR HIGH FIDELITY**



8. CHECKING THE MOTHER

Quality control is of utmost importance in the manufacture of a record. Here a metal mother is played to verify that it is faultless. If the girl detects a flaw, a new mother will be made from the metal master.

## *Tubes, Resistors, and Capacitors*

AN AMPLIFYING TUBE is a sort of electronic gate, which controls the flow of electricity through the circuit. A *power supply* provides a source of electric current for all the tubes in an amplifier, and the power supply derives *its* power from the 110-volt supply in the home. (This explains why an amplifier must be plugged into a wall outlet.) This constant flow of electricity, applied to the amplifying tube, causes it to pass a steady current which, because it is unchanging, produces no audible impulses. The audio signal that we wish to amplify is applied to the *input* of the tube, where it acts as a lever to vary the amount of electric current flowing through the tube from its power supply. A very small impulse applied to the tube's input lever, known as the *control grid,* causes a very large change in the current flow through the tube. In other words, we use a small electrical

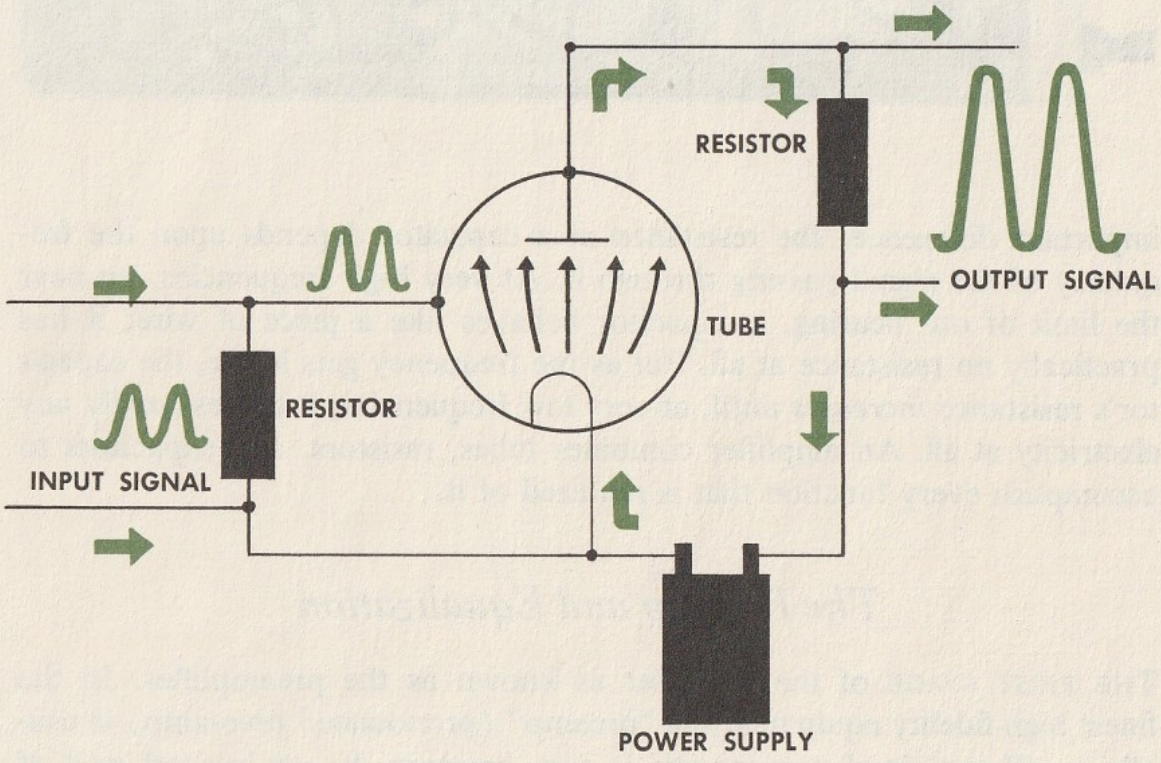
signal to cause a large change in electric current, and the result is *amplification* of the original electrical impulse.

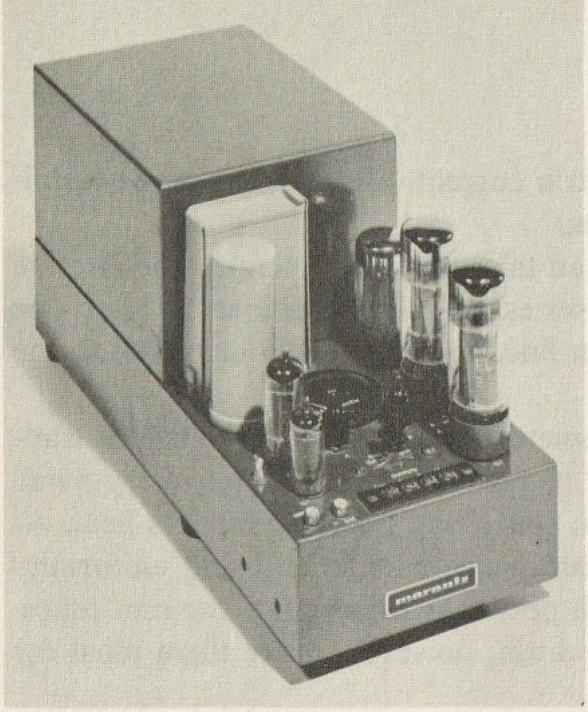
The amount of amplification that can take place in a single tube is quite limited, but by connecting a whole series of tubes together so that one feeds its amplified signal to the next in line, there is hardly any limit to the amount of amplification we can get.

One of the latest electronic developments in amplifiers is the use of transistors. These take the place of tubes to provide amplification. Very small in comparison, they take up almost no space and generate far less heat. At the moment their two disadvantages are lack of manufacturing uniformity and inability to deliver nearly as much power as top-quality vacuum tubes. Their small size and very low current drain, however, make them ideal for miniature portable equipment.

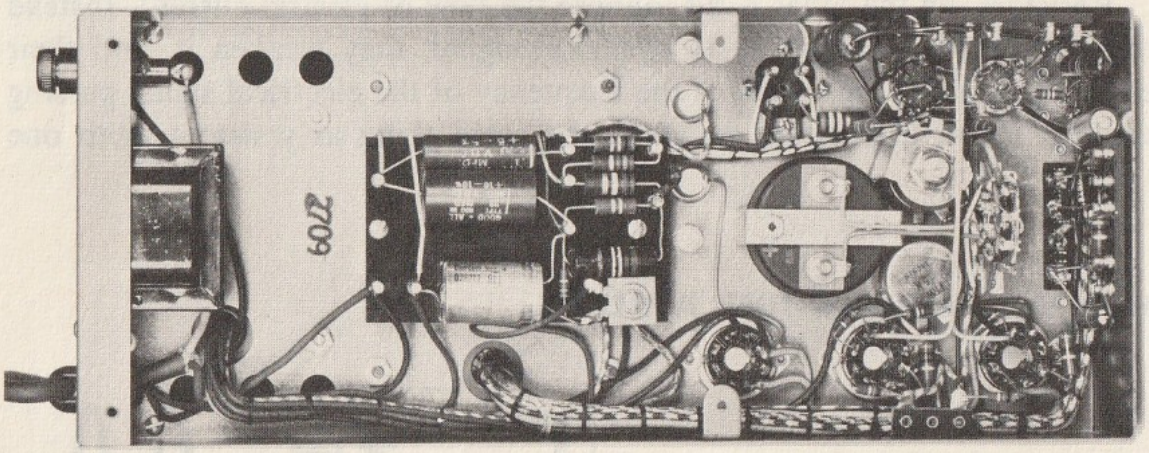
Resistors, on the other hand, *oppose* the flow of electric current. Instead of boosting the strength of an electrical signal, they weaken it, and their effect is the same regardless of the frequency of the electrical signal passing through them. Capacitors do much the same thing as resistors, with one

**HOW AN AMPLIFIER TUBE AMPLIFIES**






The Marantz Model 5 monophonic single-channel amplifier in operation, and an underchassis view showing the intricate, but orderly, wiring.




important difference: the resistance of a capacitor depends upon the frequency of the signal passing through it. At very high frequencies, up near the limit of our hearing, a capacitor behaves like a piece of wire; it has practically no resistance at all. But as the frequency gets lower, the capacitor's resistance *increases* until, at very low frequencies, it passes hardly any electricity at all. An amplifier combines tubes, resistors, and capacitors to accomplish every function that is required of it.

## *The Preamp and Equalization*

THE FIRST STAGE of the amplifier as known as the preamplifier. In the finest high-fidelity equipment the "preamp" (pronounced pree-amp) is usually a self-contained component. It can, however, be an integral part of

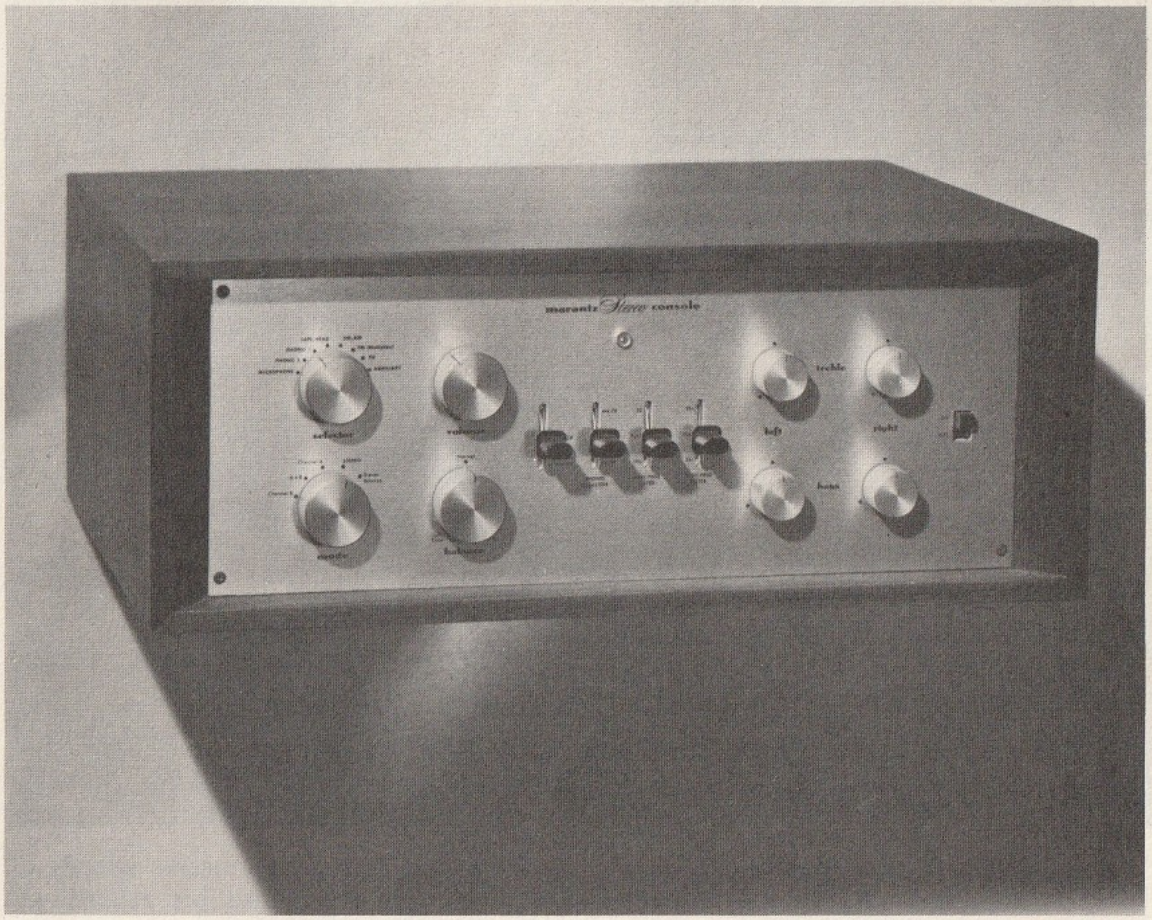
the main amplifier. The preamp uses one or two amplifying tubes to give the extremely weak signals from the pickup their first boost.

Recording engineers have found that records are easier to cut when their bass tones are weakened and their treble frequencies are emphasized in volume. The final record is then played back with an equal amount of bass boost and treble reduction, or *rolloff*. This tonal correction that takes place during playback of the record is known as *equalization,* and it generally takes place in the preamp.

The equalizer is a combination of resistors and capacitors which offer maximum resistance to treble tones and minimum resistance to bass tones in order to give treble reduction and bass boost.

The preamplified and equalized signal voltages are next fed into the preamp's control stage, with its familiar control knobs that allow us to adjust the volume and the tonal balance of the sound.

Marantz Model 7 *Stereo* Console—the preamp that sets the industry standard.



Les Paul and Mary Ford have become famous for the distinctive sounds of their records. He acts as his own engineer for these multiple recordings.

The volume control is nothing more than a resistor whose effectiveness can be changed by rotating a knob. With the control turned up all the way, the reproducing system will work at its maximum volume, which may be enough to rattle the windows and is certainly too loud to listen to. Turning the knob down increases the amount of resistance to the electrical signals, weakening them to the point where the system's volume meets our needs. Further resistance puts the sound into the background, so we can talk over it, while a still further reduction makes the sound too soft to be heard at all.

Tone controls are, in effect, variable equalizers which allow us to make further adjustments in the tonal balance of the signal already achieved by equalizing in the previous stage. Because these bass and treble controls do change the balance of the original signal, it is easy to see how they could spoil genuine fidelity if they are misused. But some records do have too much or too little bass or treble, and these controls allow us to correct for these "mistakes" in the recording. In general, though, it is best to leave these controls in their "flat" or mid-way positions all the time, because their misadjustments can neatly do away with all the built-in fidelity of even the best (and most expensive) reproducing systems.

The control section also adds some amplification of the signal, and then passes it on to the main amplifier and its output stage. The final step in this particular stage is the *output transformer*. Generally speaking, the bigger the transformer, the higher will be the fidelity. The output transformer

Marantz Model 9 70-watt power amplifier. This is one of the biggest amplifiers made, and one of the best.

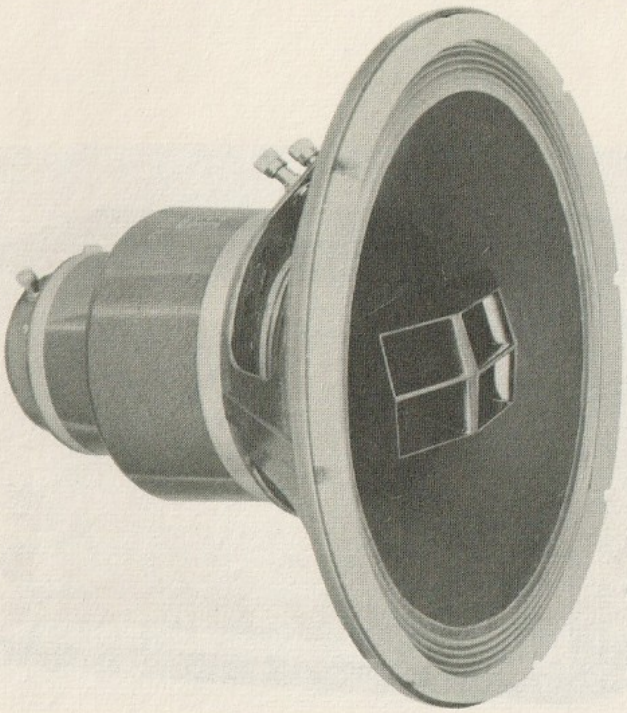
gives the signal the power it needs to vibrate the loudspeaker cone back and forth. The more *watts* of power an amplifier can put out, the louder the sound which the loudspeaker can produce without audible distortion.

Normally, an amplifier's power output will increase by the same amount that we increase the signal being fed into it. However, if we increase its input signal to the point where the amplifier is putting out as much power as it possibly can, further increases in the input signal will simply cause the output stage to slice the tops off the electrical impulses, causing horrible distortion of the sound. This *overload* point, then, is something we should try to stay away from if we want our amplifier to be an accurate reproducer.

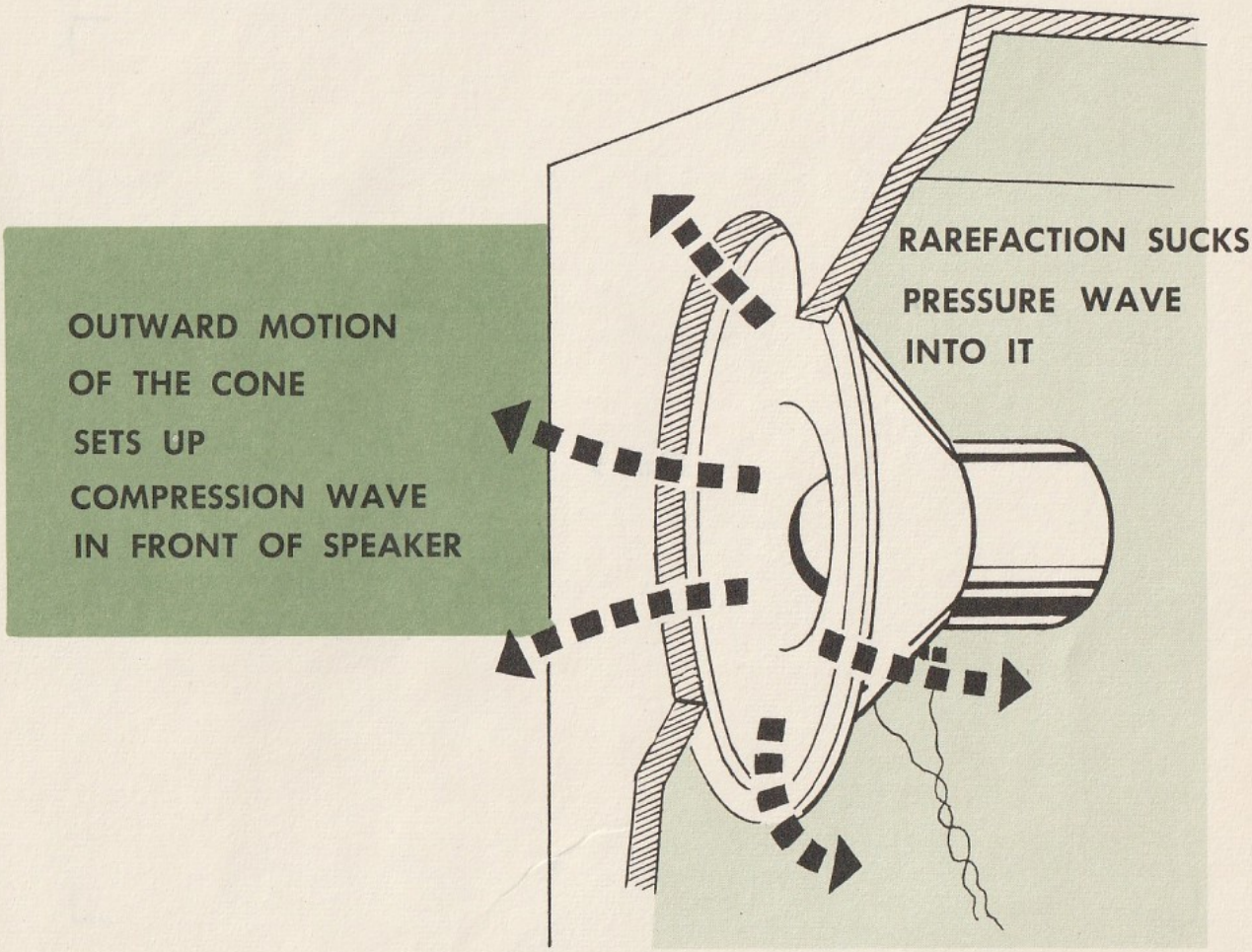
This we can do by using an amplifier whose power-output capability is high enough so that, at the volume at which we listen to music, we will never drive the amplifier to its maximum power-output point.

## *How Many Loudspeakers?*

IN ITS SIMPLEST FORM, the loudspeaker is a paper cone with an attachment that vibrates it in accordance with electrical impulses. But there are several reasons why this simple arrangement cannot give the best fidelity.

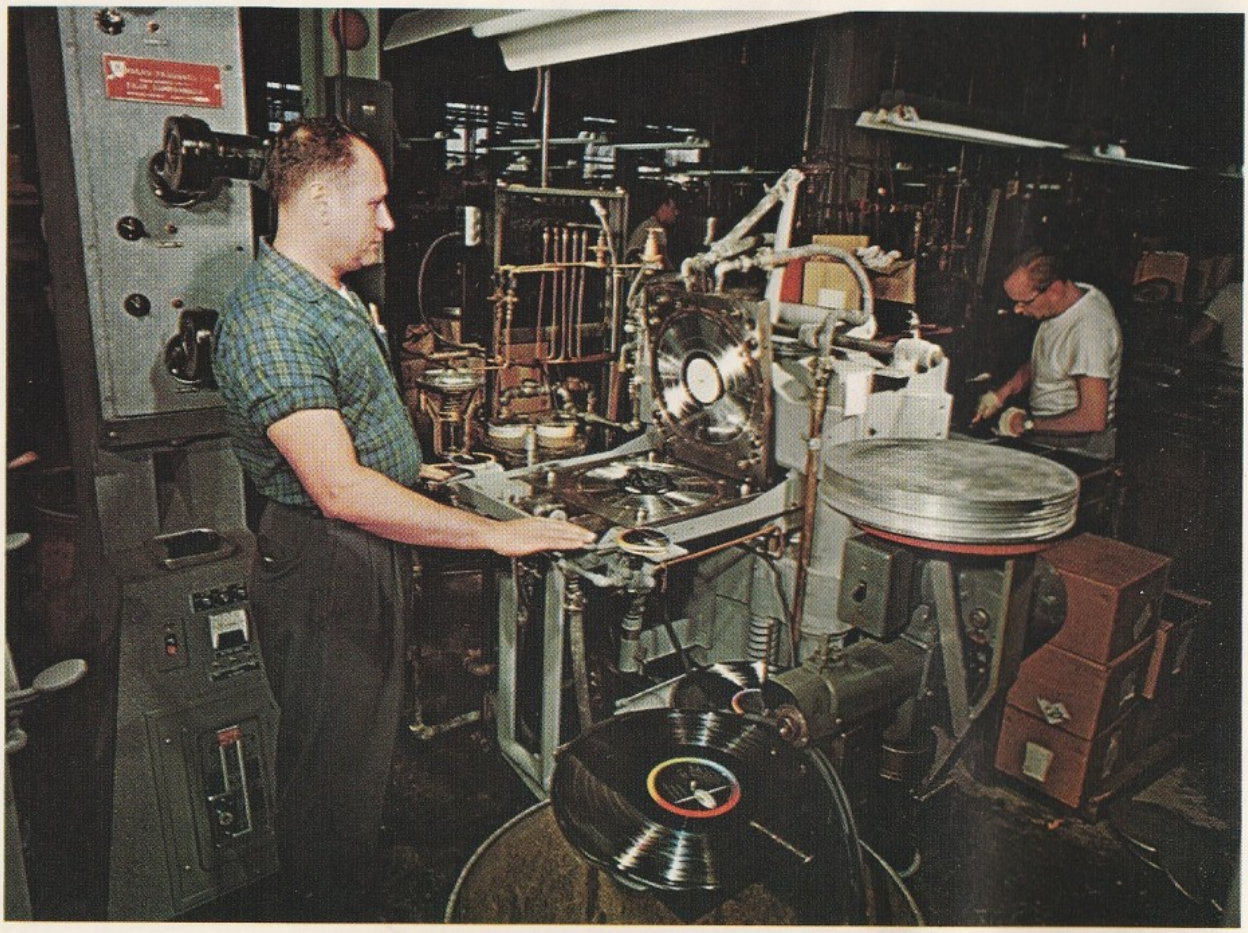


Two loudspeakers in one: the Altec-Lansing 605A Duplex is 15 ins. in diameter. The larger tubular section at the rear drives the low-frequency cone (woofer) and the smaller section drives the high-frequency horn in the center.




When a cone vibrates outward, it sets up a pressure wave in front of it. At the same time, a rarefaction—a low-pressure area—is set up behind it, and if there is any way for the pressure wave to get around behind the cone and fill up the rarefaction, it will do this. The result will be a weakening of the pressure wave and, since this effect is most noticeable at low frequencies, the sound we hear will lack bass because of this thinning-out effect. To prevent this, then, the loudspeaker is mounted in a hole in the side of a cabinet or enclosure, which seals off the front wave from the back wave.

Bass tones involve fairly substantial movements of the air, and these call for a rather large vibrating surface. In other words, for full bass response, the loudspeaker cone should be quite large. A large object, however, tends to be rather heavy, and the heavier something is, the less easily it can change direction once it starts to move. Consequently, while a large cone



9. PRESSING A VINYL BISCUIT WITH TWO STAMPERS

Capitol Records pressing room foreman operates their newest press. Stampers, made from the mothers, are locked in place, labels are located, and a heated vinyl biscuit is ready to be pressed. It will emerge a 12-inch long-playing disc.

will reproduce good bass, it is not able to cope with the rapid vibrations of high frequencies, so the loudspeaker cone cannot be made too big, either.

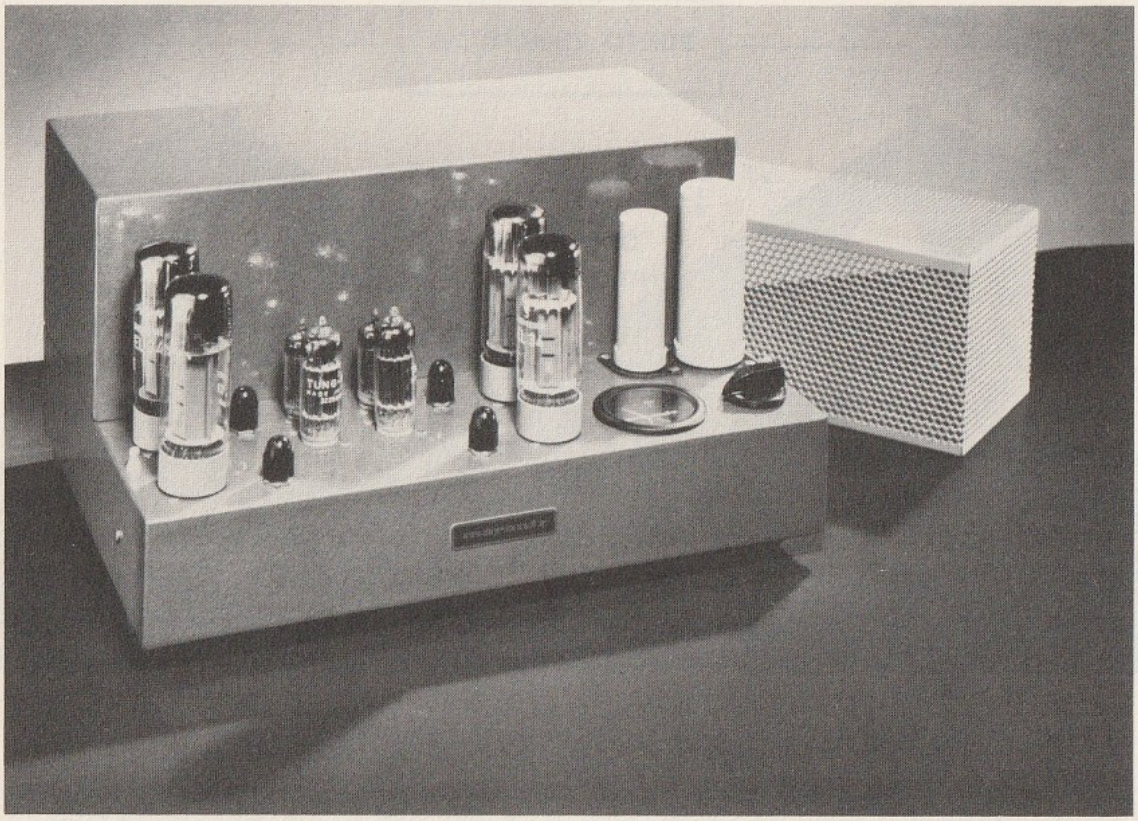
The entire audible range is best covered by two or more separate loudspeakers, each designed specifically for the tonal range it is supposed to encompass. Some loudspeaker systems have as many as six separate speakers, each covering a different part of the audible range, but equally good results have actually been obtained with two-way systems. A single-cone speaker is a compromise arrangement, but beyond that, the number of separate speakers in a system is not necessarily an indication of the system's quality.

# THE STEREOPHONIC SYSTEM

A MONOPHONIC REPRODUCING SYSTEM consists of one turntable, pickup, amplifier, and loudspeaker, in that order. A stereophonic system also uses a single turntable and pickup, but the pickup has two separate output connections, and these feed two separate amplifying channels and two identical loudspeakers.

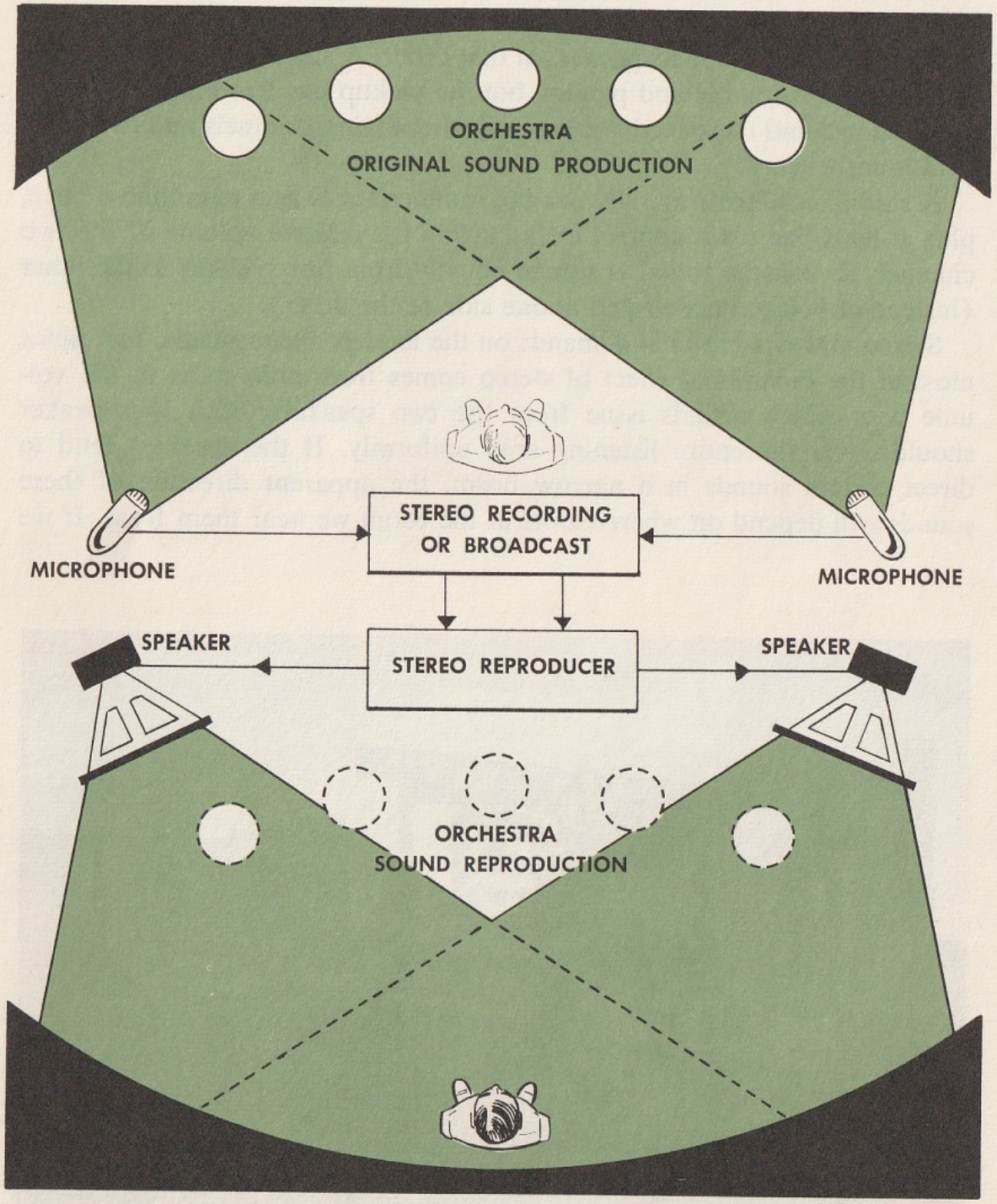
A stereo amplifier generally has the same controls as a monophonic one, plus at least one extra control for adjusting the relative volume of the two channels so that the sound is spread equally from one speaker to the other (instead of being concentrated at one side or the other).

Stereo makes additional demands on the loudspeaker systems, too. Since most of the directional effect of stereo comes from differences in the volume with which sounds issue from the two speakers, each loudspeaker should cover the entire listening area uniformly. If the speakers tend to direct certain sounds in a narrow beam, the apparent direction of these sounds will depend on whereabouts in the room we hear them from. If we



Marantz Model 8 stereophonic two-channel power amplifier.

## STEREOPHONIC SOUND




*Top:* Two microphones have been placed in an auditorium or a studio so as to cover, between them, the whole orchestra. Obviously the left mike will pick up louder sounds from the left-hand side, and conversely for the right-hand mike. When the music is reproduced in the home with two widely spaced loudspeakers, the original orchestra seems to be re-created between the speakers.

One of the production nerve centers at Capitol Records pressing plant in Scranton, Pa., is shown here. Master charts are kept of the work flow as well as all the current record labels. Imagine the confusion if the wrong labels were affixed to the records.

10. CHECKING PRODUCTION FLOW

stand in the beam from one speaker, all sounds will appear to come from it instead of from their proper place somewhere between the speakers. The ears *can* be fooled into "hearing" sounds coming from the area between the speakers, but if the speakers themselves are not well suited for stereo, the ears will refuse to give us the effect we are trying to achieve—that of a continuous "curtain of sound" between the loudspeakers. This is one reason why the speakers should, ideally, be identical twins.

## *What Else, Besides Records?*

PHONOGRAPH RECORDS PROVIDE MOST of the program material for home high-fidelity systems, but there are other sources of music available to anyone with the extra money to spend and whose hi-fi amplifier is equipped to handle them.

Additional input receptacles are provided at the rear of most hi-fi amplifiers for attaching a radio tuner, TV tuner, or tape recorder. And a selector switch on the amplifier's front panel allows anything plugged into these receptacles to be reproduced through the hi-fi system.

A radio tuner is simply a refined version of the "front end" of a conventional radio set. It contains the receiving section of an AM or FM set (or a combination of both), and lacks only the conventional radio's output stage and loudspeaker. The tuner puts out a fairly strong signal (requiring neither preamplification nor equalization), so it can be fed right into the control stage of the amplifier, which is where the input selector is located.

Stereo tuners provide the necessary two outputs for receiving stereophonic broadcasts, while a television tuner is much the same as an ordinary radio tuner except that it also includes the picture tube and all its associated equipment. The sound portion of the TV tuner may be connected into the appropriate receptacle in the hi-fi preamplifier.

Does your Representative or your Senator keep in touch with his constituents by speaking over a local radio station? Very probably he recorded his talk in this transcription room in Washington, D. C.

# TAPE AND FILM RECORDING

SHORTLY AFTER PHONOGRAPH RECORDS went electronic, the movie industry found a practical way of adding sound to the previously silent movies. Phonograph records had been tried in this connection, but it was impossible to keep their sounds in step with the film well enough to synchronize lip movements with their corresponding sounds. "Lip-synchronous" sound called for something that was tied directly to the film, and *optical recording* was the answer.

A small strip along one edge of the film, outside the picture area, was designated as the sound track. When a film was made, microphones picked up the actors' voices, amplifiers boosted the signals, and an optical recorder converted them into variations in the brilliance of a light beam. This beam, concentrated onto the sound track, gave a series of light and dark areas which corresponded to the original sounds. Another variation of this technique laid a line of varying *width* along the sound track, but the result was the same: a permanent record of air vibrations, recorded in terms of light and shade.

A light-sensitive *photoelectric cell* was used to convert these shadings back into an audio signal, which remained perfectly synchronized with the action on the picture frames next to the sound track.

11. TESTING A NEW PRESSING

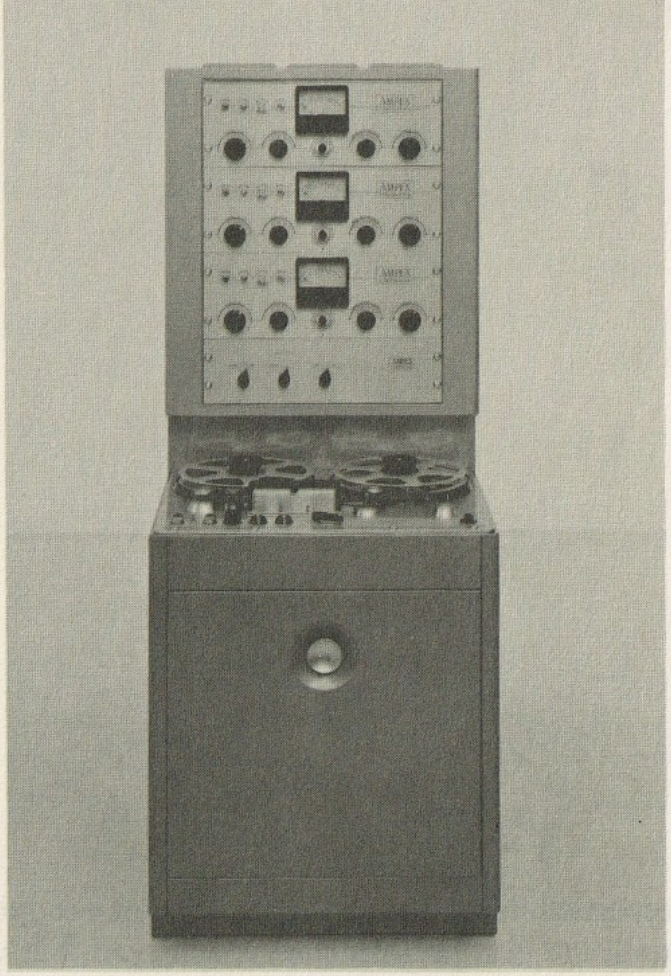
If you buy a record that has bad pops and scratches on it, you return it to the dealer. He in turn returns it to the manufacturer. This does not happen very often because of the constant testing and checking of the product. Here a girl listens to a pressing selected at random. If there is a fault, then the stamper is replaced and all records made from it since the last audio check are scrapped.

One musical film was made using two separate and interlocked films, one carrying the picture and the other carrying several *stereophonic* sound channels, but stereo did not come into widespread use in movies until *magnetic recording* came along.

Some sixty years ago, a Dane named Valdemar Poulsen was granted a patent for the first magnetic recorder. This recorded the audio signals along a fine steel wire, in the form of variations in the strength of magnetization. Although completely invisible to the eye, these variations in magnetic force along the wire could be converted back into electrical signals simply by running the wire through the same "head" arrangement that had been used to record it.

Wire proved to be unmanageable and of dubious fidelity, and the Germans proved during the late 1940s that much better results could be obtained from a plastic tape with a layer of fine iron oxide (rust) particles on it. Today, tape recording has replaced wire recording in all hi-fi applications, and the ease with which tape can be cut and spliced together again to form a perfect join has made it a godsend for the recording industry. Instead of being able to record only about seven minutes of music (one side of a 12-inch 78 rpm disk), stopping and then starting again on a new disk, recording engineers could now record most works in their entirety if they so wished.

Today it is standard practice in the recording industry for every musical work, whether it is a classical symphony or a "pop standard," to be



*Below:* Looking through the control-room window at Dinah Shore during a recording session. *Right:* An Ampex 300-3 tape recorder. This is the professional machine on which almost all three-channel stereo tapes are now made. It uses ½-inch-wide magnetic tape.

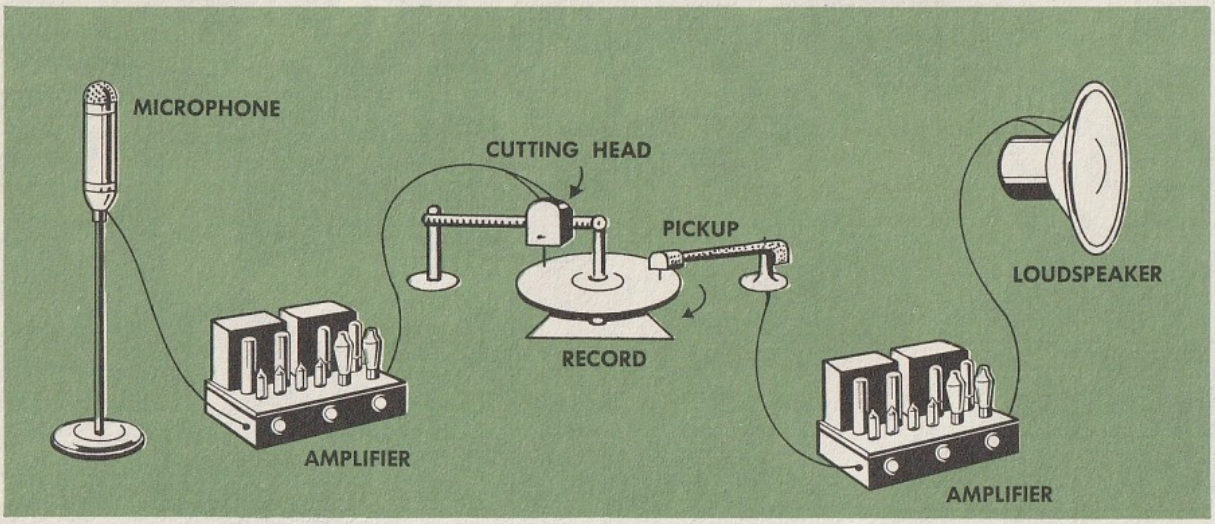
12. INSPECTION AND ANTI-STATIC WIPING

Each new record is wiped with an antistatic cloth and inserted in its jacket. Once again every single record is examined for possible flaws. All record companies, large and small, pride themselves on their quality control. In the large majority of instances the quality of the record far surpasses the quality of the instrument on which it is played.

recorded directly on to tape. This may require several "takes," or attempts, until the best performance is achieved, but when the recording sessions are over, the best takes are selected and then spliced together to make the *master tape*.

The audio signals on this master tape are then transferred to a disc, which is duplicated and sold in stores. The latest professional tape re-

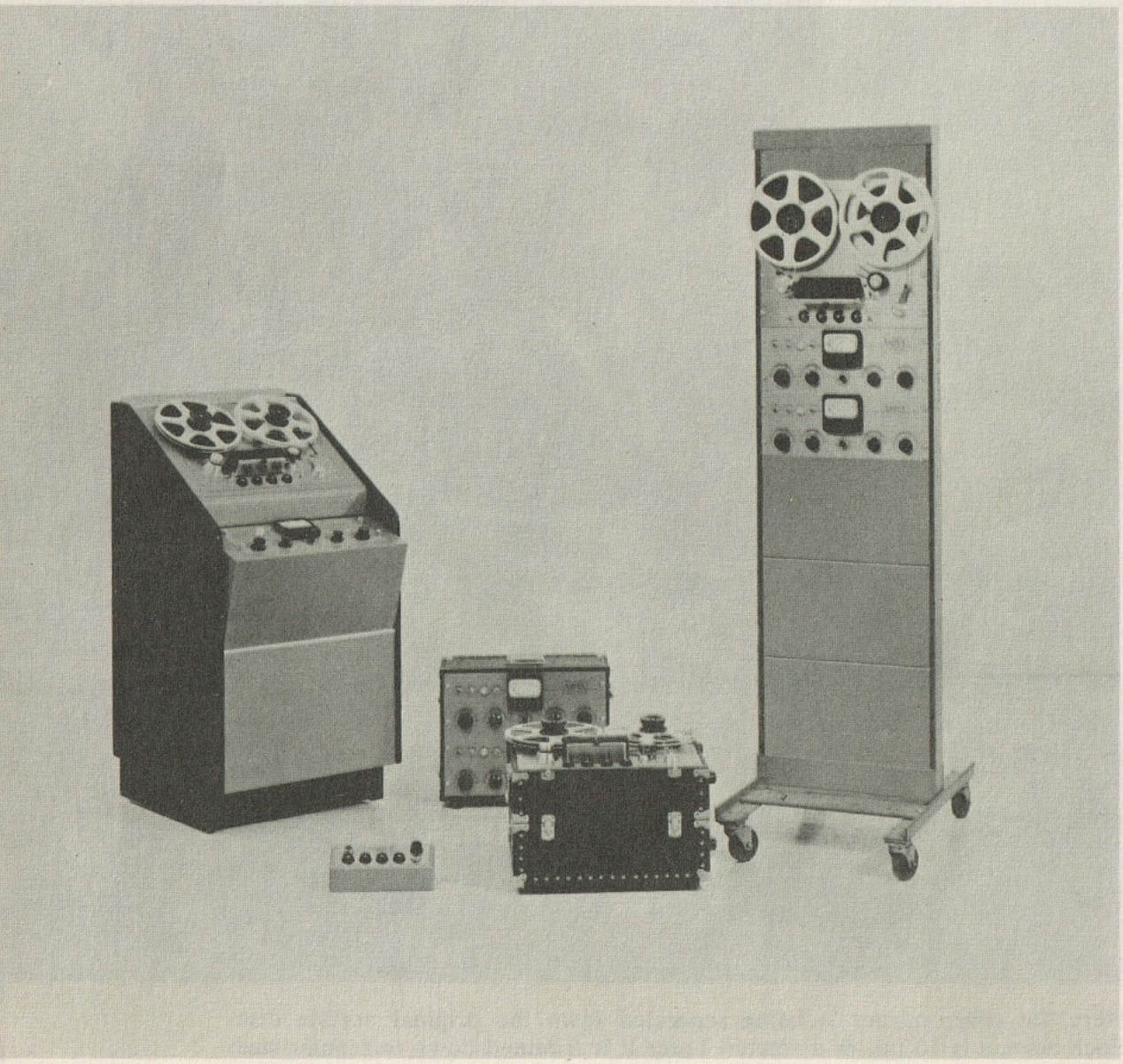
## THE ELEMENTS OF A RECORDING AND REPRODUCING SYSTEM



Here the silver master is being separated from the original acetate disc. Each acetate is 16 ins. in diameter. Later it is trimmed down to regular size.

corders, together with extremely high-quality microphones, are capable of the last word in high fidelity. In all subsequent duplication processes, compromises must be made – all of which tend to lower the fidelity to some degree. Even if you cannot hear the difference, engineers can certainly measure it!

Ampex professional equipment sets the standard in the recording industry throughout the world. From left to right they are: 351 mono in console; 351-2 stereo in two portable cases; 351-2 stereo rack-mounted on a dolly. The small box in the foreground is for remote control operation of any of these machines.

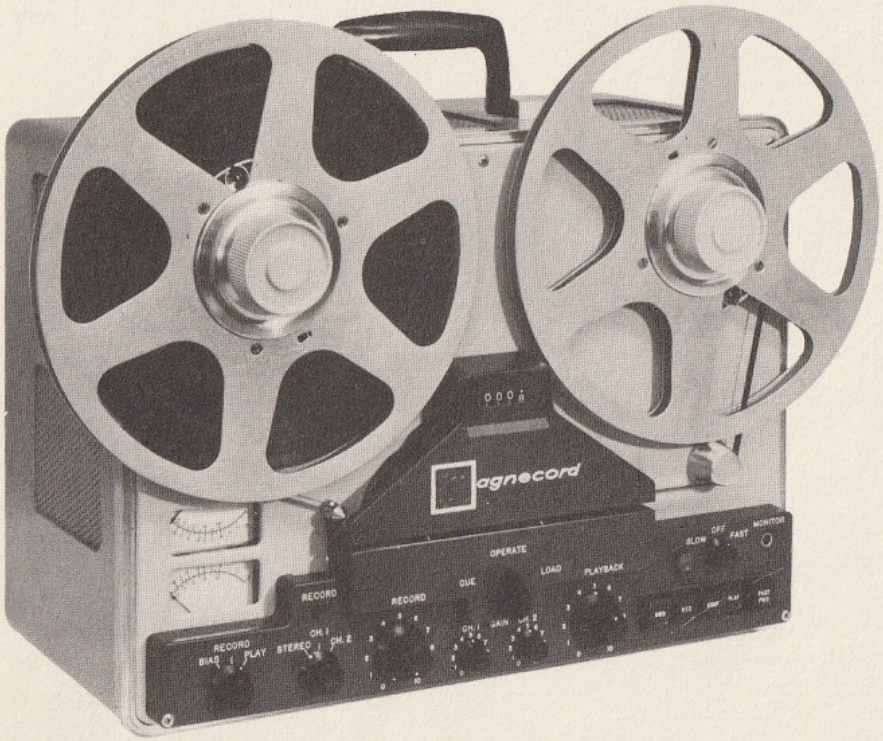


13. RECORDS IN INNER SLEEVES INSERTED IN JACKETS

Records which have already been placed inside protective inner sleeves are here inspected once more and then placed in their eye-catching jackets.

## *Tape Recordings at Home*

THE EASE WITH WHICH a magnetic recording can be made, plus the fact that the tape can be erased (by wiping off its magnetism) and used again, makes it ideal for home recording. Tape recorder owners can assemble complete libraries of tapes for their own private use made from radio broadcasts, from borrowed phonograph records, and even from "family musicales" performed right in the living room. (But remember, it is illegal to sell them.) And tape is a natural for stereophonic sound, because the separate signals (two, three, or four channels) can be recorded side by side on parallel tracks, each occupying only a portion of the width of the tape.




The Magnecord 728 tape recorder provides high standards of operating quality for the professional user and portability for the serious amateur at home.

Because of its tremendous resistance to wear and its freedom from the clicks and pops that afflict discs if they aren't kept clean and free of scratches, tape is a far better home-music medium than the disc. Also, discs wear out, tape does not. Many record manufacturers *are* selling *pre-recorded tapes* of the same music they put on discs.

## *Magnetic Film and the Cinema*

MAGNETIC FILM HAS BECOME essential as the means for bringing true high-fidelity stereophonic sound to the moving picture theater. The magnetic film is just like ordinary movie film, even to the sprocket holes along both edges for the projector's gear teeth. But instead of a series of picture frames, it carries a continuous strip of magnetic coating that occupies almost the full width of the film. The magnetic area is so wide that as many as seven or eight separate tracks can be recorded side by side on it, enabling movie makers to throw sounds at us from the sides and back of the hall as well as from behind the screen.

# ELECTRONIC MUSIC

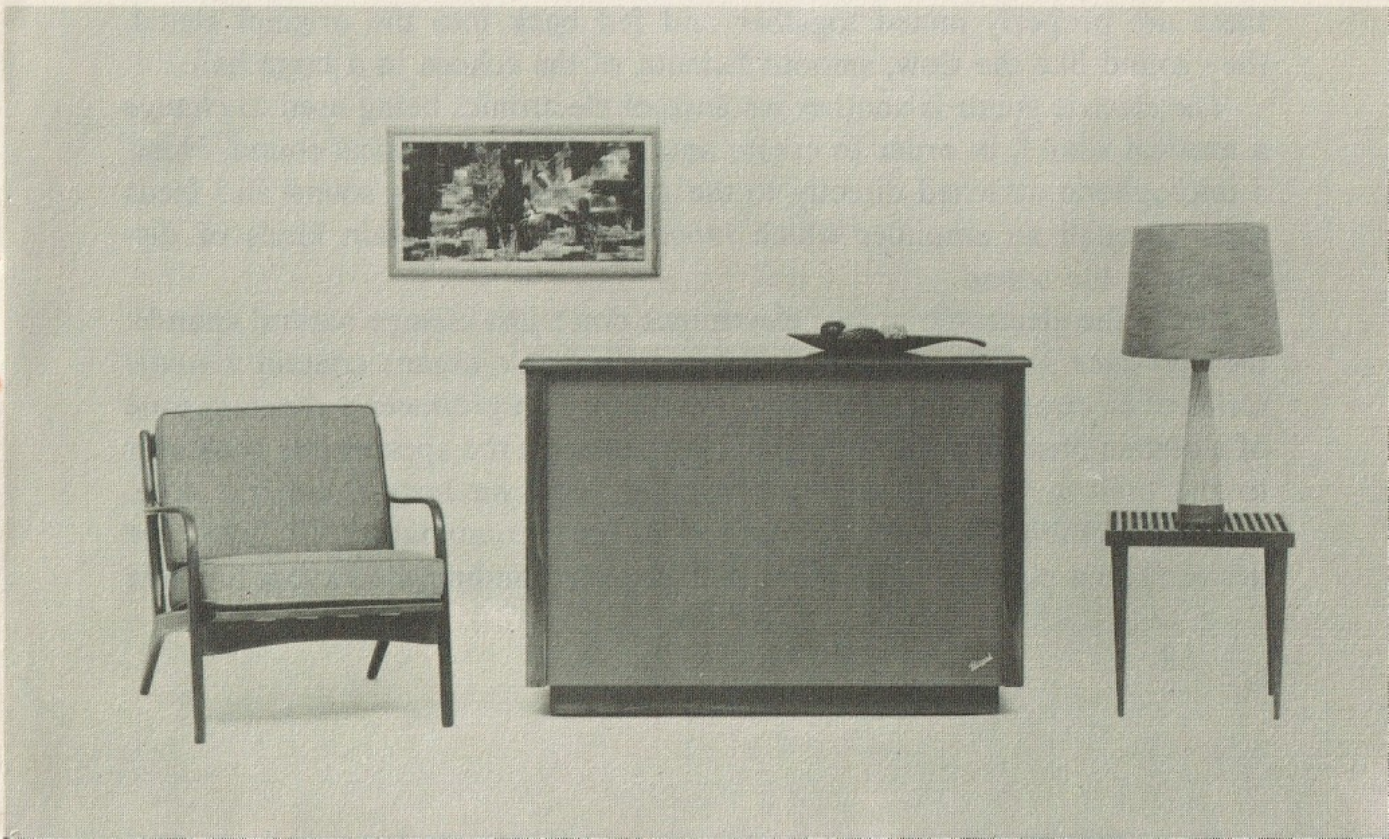
SO FAR, WE HAVE SEEN HOW electronics can reproduce natural sounds with a high degree of realism. But electronics are also being put to work in the actual *making* of musical sounds.

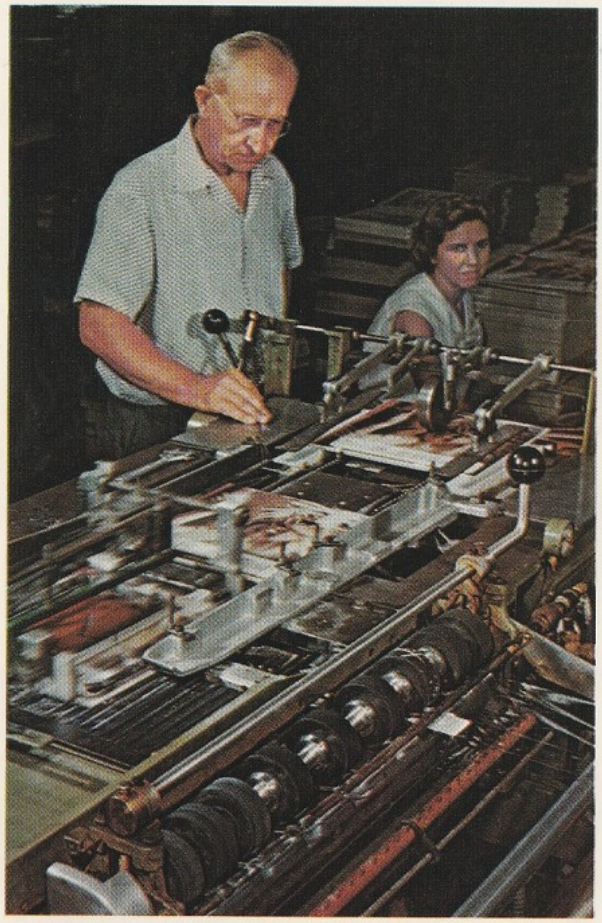
Many of the recordings we hear that sound as if they were recorded in a huge hall with lots and lots of echo were actually recorded in a studio with hardly any echo at all. The echo was added electronically.

One way of doing this is to set up a loudspeaker and a microphone at opposite ends of a long, completely unfurnished room, and feed some of the audio signal to the loudspeaker. The microphone picks up the sounds, greatly blurred by echoes, and this is mixed back into the original audio signal before it gets to the recording head. Just by manipulating the mixing control, the recording engineer can add as much or as little echo to the sound as he wants.

If we don't happen to have such an echo chamber handy, we can use a special tape machine to create the artificial reverberation. A reverberation generator uses a continuous loop of tape, and a recording head followed by a series of playback heads. When sounds are fed to the machine, they are recorded and then passed over each of the playback heads in rapid

One of the finest electrodynamic loudspeaker systems made today is the Bozak B-400. It is 50 ins. wide, 21 ins. deep, and 34½ ins. high. It has a total of 14 speakers inside the cabinet. It is a monophonic system.





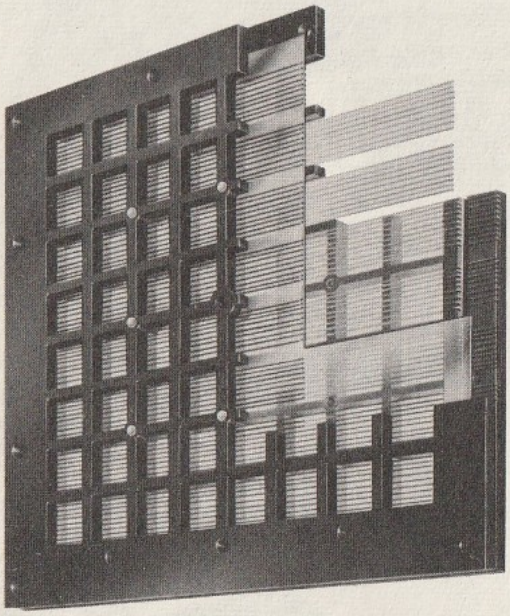
14. SEALED IN CLEAR PLASTIC FILM

This is the final step in the manufacture of a record at the Capitol pressing plant in Scranton. Here the record, in its jacket, is being wrapped and sealed in clear plastic film.

succession. The result is a series of repetitions of each sound, and when these are properly mixed together and fed back into the original signal, they sound like the slow, smooth fadeout of the echoes in a large hall.

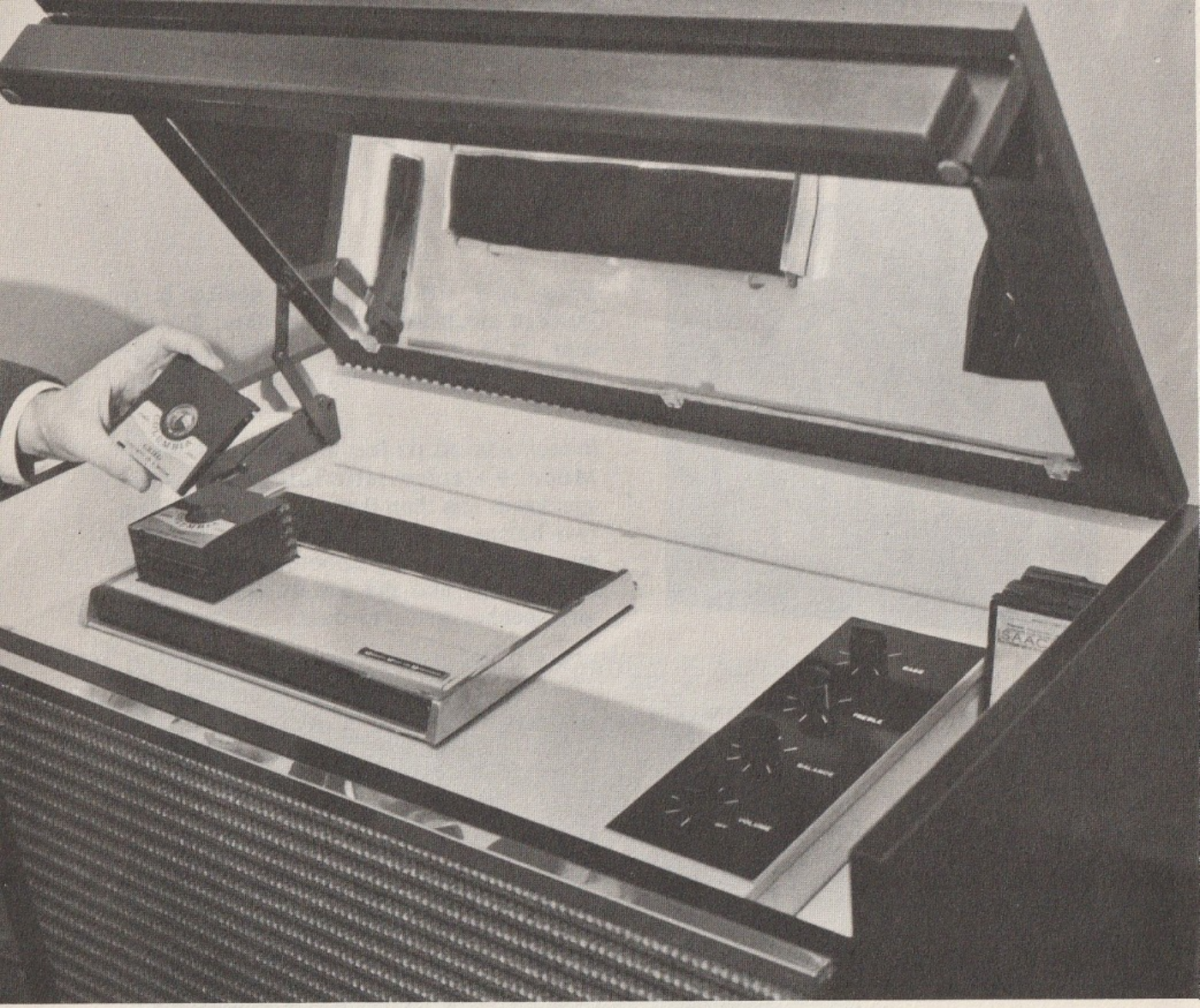
The electric guitar is another instance of electronics being used to *change* a musical sound, in order to create another different musical sound. Here, a microphone attached directly to the guitar picks up its sound and feeds these through an amplifier which *intentionally* adds certain kinds of distortion to the sound.

But in the electronic organ, electronics don't just change natural sounds; they *produce* sounds of their own. Most electronic organs contain a whole series of electronic tone generators, each of which produces a constant tone of a certain musical pitch. Pressing a key connects the appropriate generator to the built-in amplifier and loudspeaker, and we hear a musical note. Pressing combinations of keys gives us any combination of notes we desire (like a piano), while other switches surrounding the keyboard allow



*Left:* This strange-looking device is a JansZen electrostatic loudspeaker. It consists of a micro-thin diaphragm sandwiches between two layers of conducting wires.

*Below:* Almost six feet high, the new KLH Model 9 electrostatic full-range loudspeaker is less than three inches thick. The two halves separate for stereo use. This system provides the smoothest and widest tonal range and the lowest distortion of any speaker made to date.



The shape of music to come? This is a pre-production model of a new recording and playback system for stereophonic music. It was developed by CBS Laboratories under a research program conducted for Minnesota Mining & Manufacturing Company. It uses magnetic tape at an operating speed of 1⅞ i.p.s. and the diminutive tape cartridges may be stacked to provide up to six hours of continuous musical program.

us to select different tone-control combinations to give the tones any desired quality or timbre.

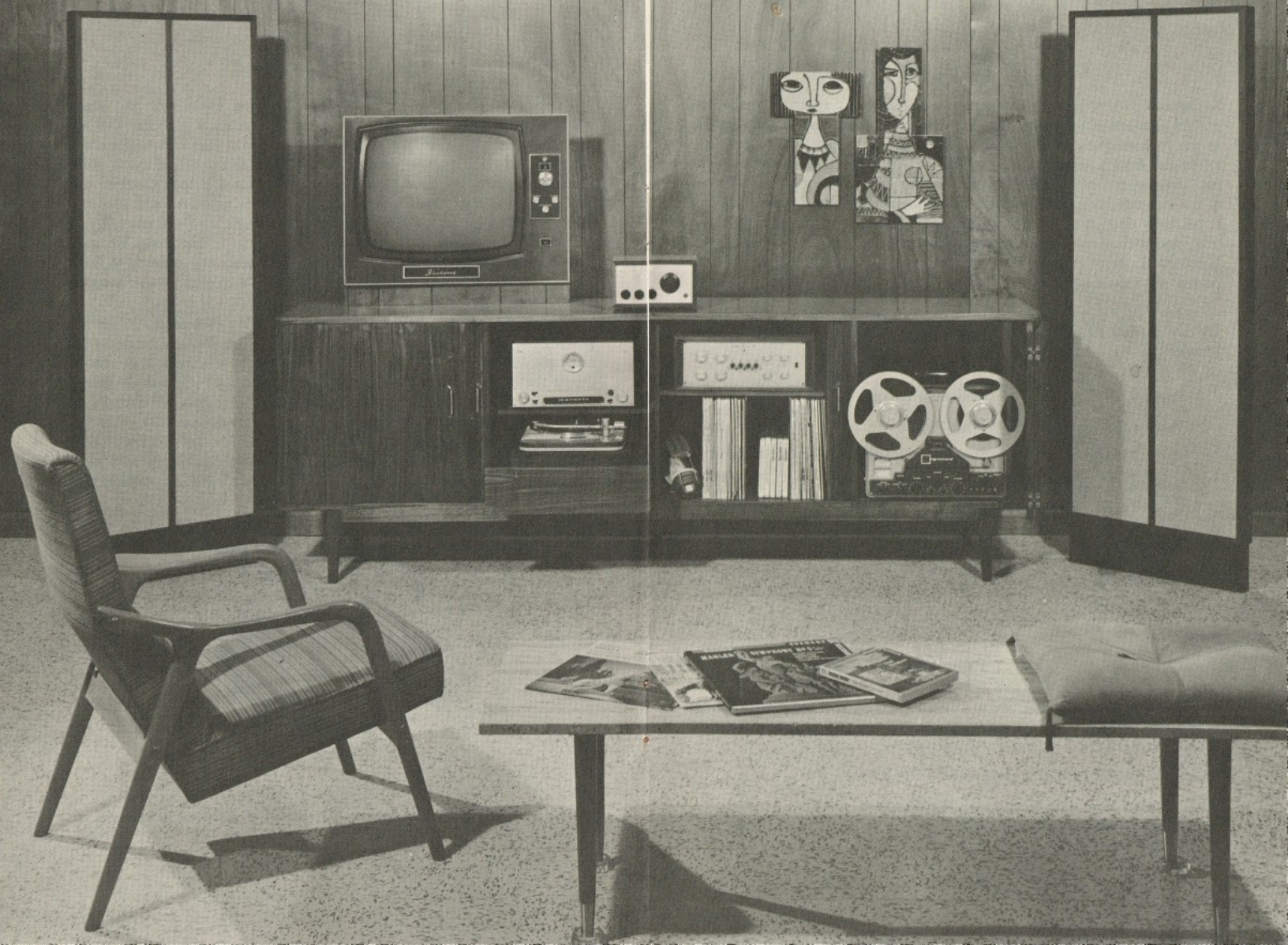
Electronics and music have probably reached their closest alliance in the field of so-called tape recorder music, where tape recordings of musical and nonmusical sounds are speeded up, slowed down, run backwards, and intermixed to create a totally new sound in which the original sounds are almost impossible to discern or recognize. Weird as it may sound, some people find it enjoyable!

## *What's in the Future?*

NO ONE CAN REALLY PREDICT in what direction electronics and music will take each other in the near future, but it appears at this time that the next thing we will see will be stereophonic tape in a sealed cartridge about the size of a thick graham cracker. These tape cartridges, sold with music already recorded on them, will play on an automatic tape changer that will take enough of them to give us a full day's uninterrupted listening. Discs will be with us for a long, long time, though, and will probably be the preferred medium for most high-fidelity stereo in the home for some time to come. Professional users, however, will probably continue to favor ¼-inch two-track or ½-inch three-track tape until an entirely new medium comes along.

What next? Nobody knows, although something that seems to be appearing on the far distant horizon is an entirely new form of home entertainment: *direct* stimulation of the human brain by electrical impulses, to create the *complete* illusion of sight, sound, taste, and physical sensation. When that comes, fifty or a hundred years from now, man will actually be a *part* of the electronic circuits that record and reproduce sounds and other physical sensations. The blind will see electronically, the deaf will hear electronically, and anyone will be able to reproduce inside his own head every aspect of an evening at a concert through the achievement of electronics.

*Next page:* This system of individual components can truly be said to reproduce music with utmost high fidelity.



# ABOUT THE AUTHOR

J. GORDON HOLT, a native American, was raised and educated up to his middle high-school years in Australia, where, he insists, they teach English as the Aussies speak it. He ended up back in the United States where he graduated from Lehigh University with an A.B. in journalism. He spent four years as technical editor of *High Fidelity Magazine,* one year as head of the technical services division of hi-fi manufacturer Weathers Industries, is currently doing free-lance writing and consulting work for hi-fi publications and manufacturers. He is recording engineer for the internationally famous folk singer Richard Dyer-Bennet, who releases his own recordings on his own record label.

We are indebted to the following for illustrations which appear in this booklet:

| | |
|---|---|
| Pages 4, 9 | Columbia Records |
| Pages 12, 40, 48, 51, 53 | Wide World |
| Pages 13, 14 | Symphonic Radio and Electronic Corp. |
| Page 16 | RCA Victor |
| Pages 21, 22 | Gotham Audio Corporation |
| Page 59 top | Neshaminy Electronic Corp. |
| Pages 62-63 | AUDIO Magazine |

*Color Plates*

| | |
|---|---|
| Plates 2, 3 | Photo Researchers, Inc. |

We wish to express our gratitude to Capitol Records, Inc. for allowing us to take photographs at their recording session (Plate 1) and at their Pressing Plant in Scranton, Pa. (Plates 4 through 14).

The cover for this booklet was painted by GIL EVANS.

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the spot illustrations by FRANK LACANO.

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